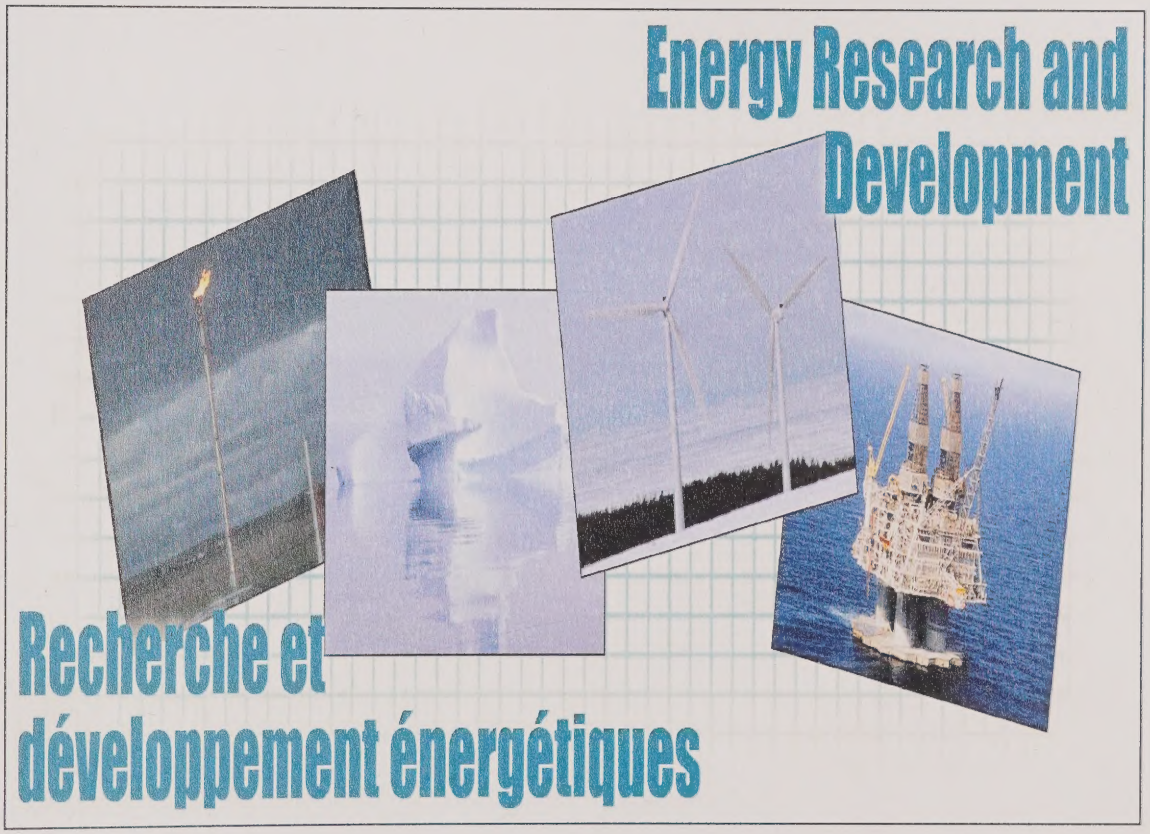
PERD

Program of Energy Research and Development at Environment Canada:

1999–2001

A Two-Year Review

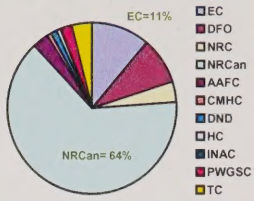


The Program of Energy Research and Development at Environment Canada

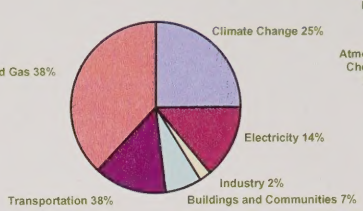
The Goal

Making sustainable development a reality in Canada by helping Canadians live and prosper in an environment that needs to be respected, protected and conserved.

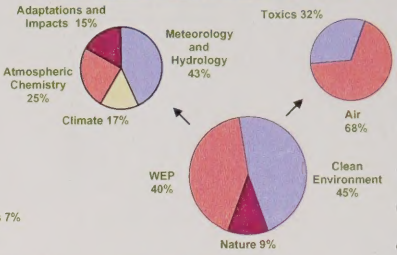
Participating Departments



EC Participation in PERD Strategic Intents



EC Breakdown of PERD Activities by Business Line



TOTAL PERD FUNDS: $57.6 M

TOTAL ENVIRONMENT CANADA ALLOTMENT: $5.3 M

Oil and Gas

Strategic Intent 1: Fulfill federal government responsibilities while maximising economic benefits and reducing environmental consequences from the expansion and diversification of Canada's oil and gas production.

Strategic Direction 2: Provide S&T to extend and diversify Canada's oil and gas production from offshore and northern regions through the development of the science and technology needed for standards and regulations, and to reduce costs and mitigate environmental and safety concerns.

Objective 1.2.1: Offshore environmental factors (OEF) for regulatory, design, safety, and economic purposes.

PROJECT TITLES:
Operational ice Modelling
Objective: Optimize sea ice and iceberg analysis and forecast capabilities of the Canadian Ice Service (CIS).

Operational Detection of Icebergs from Remotely–Sensed Data
Objective: Assess the capabilities of and develop techniques to use space-borne Synthetic Aperture Radar for detecting Icebergs.

Validation of Buoy and Platform Wind and Wave Measurements
Objective: Determine the validity of the MIROS wave system measurements and the reliability of new buoy wind and wave measurement technologies.

Offshore Wind and Wave Design Criteria
Objective: Develop methodologies to reliably determine offshore wind and wave design criteria.

Data Assimilation into Coupled Atmosphere–Ocean Wave Models
Objective: Develop a fully coupled atmospheric–wave–surface current model that is driven by a fully–coupled wind–wave data assimilation procedure.

Objective 1.2.3: Regulatory requirements for the safe and efficient transportation of oil and gas by tankers, and for other occupational and public safety standards.

PROJECT TITLES:
Prediction of Small Glacial Mass Distributions
Objective: Build a model that can predict the calving, drift and deterioration of small iceberg pieces.

Strategic Direction 3: Provide S&T to address cross–cutting environmental and safety issues to support the production of Canada's onshore and offshore oil and gas resources.

Objective 1.3.1: The regulation and reduction of GHG and other atmospheric emissions, primarily from flaring.

PROJECT TITLES:
Standards for Testing and Certification of Environmentally Efficient Flaring
Objective: Quantify flare efficiency and investigate design and operational factors to improve flare efficiency.

Objective 1.3.3: The remediation of groundwater and soil issues.

PROJECT TITLES:
Standardisation and Validation of Terrestrial Toxicity Test Procedures for Assessing Biological Effects in Hydrocarbon Contaminated Soils.
Objective: Develop and field validate terrestrial toxicity tests relevant to Canadian sites.

Pollution Prevention and Control Technologies in the Oil and Gas Industry
Objective: Evaluate natural attenuation techniques, determine the toxicity of residual soil hydrocarbons and assess the impact of added sulphur to the microbial and chemical properties of fine tailings.

Wetlands-Containment, Transformation and Remediation of Toxic Organics from Natural Gas Condensates and Process Chemicals
Objective: Determine the effectiveness of wetlands in attenuating toxic contaminants.

Biological Barriers in Fractured Bedrock
Objective: Permeability reduction and migration prevention in fractured media.

Assessment of Phytoremediation as an In–Situ Technique for Cleaning Oil Contaminated Sites
Objective: Evaluation of phytoremediation.

Simultaneous Recovery of Inorganic Contaminants and Hydrocarbons from Soils Using Chelation/Solvent Extractions
Objective: An advanced technique to extract pollutants from contaminated sites.

Assessment of Natural and Anthropogenic Impacts of Oil Sands Contaminants within the Northern River Basin
Objective: Assess the environmental impact of natural vs. anthropogenic hydrocarbon release.

Solar Detoxification
Objective: Study SolAqua process efficacy over a range of organic pollutants.

Transportation

Strategic Intent 2: Foster cleaner sustainable transportation fuels and systems in order to improve the environment, reduce emissions, including GHGs, and to increase economic activity through development of domestic and export markets.

Strategic Direction 1: Provide S&T to reduce emissions from transportation sources to improve air quality and health and reduce GHG production.

Objective 2.1.1: Support for the development of technological and other measures to control and reduce emissions of particulate matter.

PROJECT TITLES:
Determination of the Concentration, Composition and Sources of Airborne Carbonaceous Particles in Canada
Objective: Particulate characterisation to gain insights into the transportation, transformation, and fate of ambient fine particles and their precursors.

Characterization of Particulates—Transportation Fuels
Objective: Development of methods to characterise and model particles emitted by transportation sources.

Objective 2.1.2: The design and use of gaseous and liquid hydrocarbon fuels and associated technologies to achieve emissions reductions.

PROJECT TITLES:
Engine Cold Start Efficiency
Objective: Develop technologies and processes to reduce energy consumption by automobiles.

Environmental Impact of the Use of Alternative and/or New Reformulated Fuels and Development of Advanced Engine/Vehicle Technologies for Use in Light and Heavy Duty Motor Vehicles
Objective: To assess the emissions and performance of alternative fuels and advanced engine/vehicle technologies.

Environmental Properties of Diesel Ethers
Objective: Measuring environmental properties of diesel ethers and screening for potential environmental concerns.

Strategic Direction 2: Provide S&T to improve energy efficiency, reduce emissions and provide economic benefits to Canada from next generation vehicles and systems.

Objective 2.2.2: The development of fuel cell, electric and hybrid vehicle components and their supporting infrastructures.

PROJECT TITLES:
Fuel Cell Vehicle Life Cycle Emissions and Environmental Assessment
Objective: Explore the potential for using fuel cells in transportation applications and to assess the environmental implications.

Electric and Hybrid Vehicle Emissions and Environmental Assessments
Objective: Examine the potential environmental benefits of electric and hybrid vehicles.

Objective 2.2.4: The optimisation of the energy efficiency of transportation systems.

PROJECT TITLES:
The St. Lawrence Routing Management Support Model
Objective: Produce maps indexing safety and efficiency factors for safe, efficient waterway routing. Increase public awareness.

Buildings and Communities

Strategic Intent 3: Reduce the overall energy intensity of Canada's buildings and community systems and, consequently, their associated GHG emissions while, at the same time, providing Canadian companies with potential economic opportunities.

Strategic Direction 2: Provide S&T to integrate energy services (supply and end use) in communities to reduce overall energy requirements, optimise the use of available resources and reduce environmental impacts including GHG emissions.

Objective 3.2.1: The establishment of cost-effective interconnections of heat sources and sinks at the community level, which promote the use of energy appropriate to its quality.

PROJECT TITLES:
Advanced Tools and Procedures for Implementing Thermal Energy Storage in Large Institutional Buildings, Commercial Buildings and Community Oriented Applications
Objective: Fill major technical gaps to make Thermal Energy Storage (TES) a viable design option.

Objective 3.2.3: Improvements in the design and integration of energy, transportation, water and waste systems and land use to permit progressive, sustainable development of communities.

PROJECT TITLES:
Integrating Energy Systems for Sustainable Community Development
Objective: Contribute to improvements in the design and integration of energy, transportation, water and waste systems, and land use to permit progressive, sustainable development of communities.

Energy and Waste
Objective: Aims to make improvements in the design and integration of energy and waste systems.

Industry

Strategic Intent 4 : Reduce the overall energy intensity of Canada's industrial sectors and, consequently, their associated GHG emissions while, at the same time, improving productivity and providing Canadian companies with potential economic opportunities.

Strategic Direction 3: Provide S&T to advance generic energy related technologies and processes to reduce energy intensity, particularly in industry, to achieve productivity gains and reduce GHG emissions and other wastes.

Objective 4.3.3: The development of advanced technologies and products for heat management and separation including high efficiency drying.

PROJECT TITLES:
Applications of Microwave–Assisted Processes (MAP) to Solvent–Less Synthesis and to Low Solvent, Energy–Efficient Extraction
Objective: Provide Canada's synthesis and extraction industrial sector with low solvent and low energy consuming processes.

Objective 4.3.5: The development of low energy intensity bioprocessing technologies.

PROJECT TITLES:
Bioprocesses for Renewable Energy Production, and Improved Industrial Energy Efficiency in Canada
Objective: Develop enhanced bioprocess cleaning applications for Canada's energy, mining, pulp and paper, and chemical sectors.

Electricity

Strategic Intent 5: Reduce the environmental impacts of Canada's electricity infrastructure, particularly greenhouse gases, through alternative electric power generation, increased efficiency of fossil-fueled plants and strategies to capture and manage emissions.

Strategic Direction 1: Provide S&T to increase the proportion of Canada's electricity supply from renewables and distributed systems which offer improved system integration and reduced environmental impacts. (R&D activities in this area will exclusively address generic technological issues whose applications are not related to communities, buildings and industry).

Objective 5.1.1: Improving the economics and efficiency of conversion of renewable energy to electricity including related storage, hybrid, and systems technologies.

PROJECT TITLES:
Solar and Wind Energy Resource Assessment
Objective: Develop information, instruments and improved tools to increase the knowledge of the wind and solar resource assessments.

Strategic Direction 2: Provide S&T to reduce emissions and the associated environmental impacts from centralised, combustion-based electric power generation systems.

Objective 5.2.1: The Characterisation of Canadian Fuels and their Emissions (COFE) for more efficient and environmentally benign electricity generation.

PROJECT TITLES:
Environmental Contaminants in Coal and Coal By products
Objective: Characterise contaminants in coal feed stocks, stack emissions and in the environs of major power plants.

Objective 5.2.2: The conversion of fossil fuels to electricity more efficiently with ultra–low environmental emissions.

PROJECT TITLES:
Prevention, Control and Mitigation of Pollution from Stationary Combustion Sources
Objective: Understanding and minimising the environmental and health impacts of fossil fuel electricity generation.

Objective 5.2.3: The capture, treatment, transport, use and storage of CO_2 from large point sources.

PROJECT TITLES:
Sustainable Development of Coalbed Methane; A Life–Cycle Approach to Production of Fossil Energy
Objective: Develop technology to allow development of Canada's CBM resources while reducing CO_2 emission.

Climate Change

Strategic Intent 6: Minimize the negative impacts of climate change on the Canadian energy sector.

Strategic Direction 1: Provide S&T to support the Canadian energy sector's response to the impacts of climate change.

Objective 6.1.1: The development of a better understanding of the impacts of climate change on the energy sector, improvement in the forecasting of those impacts and the development of some possible response strategies.

PROJECT TITLES:
Climate and Energy in the Toronto–Niagara Region: Integration of Science and Policy
Objective: Assessment of the impacts of climate, vulnerabilities to climate and adaptive strategies to deal with the associated risks and opportunities.

Canadian Participation in FIREII/SHEBA
Objective: Contribute to knowledge of climate modelling, particularly in relation to arctic climate processes and changes.

Climate Change and Anthropogenic Aerosols
Objective: Understand how Canadian climate is affected by anthropogenic aerosols by developing a high resolution climate model in the northern latitudes (>35N).

Climate Change Impacts on Extremes of Heating, Cooling and Dehumidification Loads
Objective: Assess the impact of climate change on building energy use and propose regulation change to counter expected changes.

Sea Ice Climatology Studies
Objective: Produce an ice climate atlas and database and investigate trends an cycles in the ice climate.

Water Vapour, Water Cycling, Climate and Water Resources
Objective: Part of a large scientific effort investigating aspects of the water cycle over the Mackenzie River basin.

Climate Change and Offshore Design Criteria
Objective: Investigate marine climate change on future design considerations

Measurement of Aerosol/Cloud Feedback Relationships
Objective: Investigate the effects of anthropogenic aerosols on cloud formation.

Climate/Sea Ice Process Studies Usin Satellite Microwave
Objective: Provide a detailed assessme and interpretation of recent sea ice cove trends over important Canadian marine areas to hydrocarbon development and transportation.

Climate Change Impacts on Hydrolo Cycles and Extremes, with a Specific focus on the Hydro–Electric Industry Western Canada
Objective: 1) Develop coupled atmospheric–hydrologic models of snow ice reserves of the western Cordillera ar 2) an historical database of snow/ ice/water resources. 3) Assess the impacts on hydro–electric industry. 4) Develop a scientifically based decision framework for the optimisation of hydro–electric facilities.

Predicting Impacts of Climate Chang on the Hydrologic Cycle of Northwest Canada: Reducing the Uncertainties the Energy Sector
Objective: Model climate change impact on the hydrologic system in northern Canada using various scenarios. Searc historic data for climate change signal.

Gulf of St. Lawrence Ice-Ocean-Atmosphere Climate Change, Detecti and Impact on the Canadian Energy Sector
Objective: Model seasonal changes in weather, currents, ice, and heat/salt/nutrient/momentum content an fluxes in the St. Lawrence

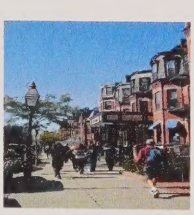
Strategic Direction 2: Provide S&T to enhance the natural uptake of GHG's fr the atmosphere.

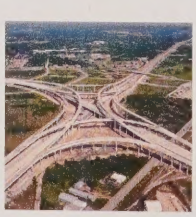
Objective 6.2.1: The development of: a better understanding of the relevant natural GHG cycles; and steps to increa the net GHG uptake from the atmosphere by forests, agricultural lands and oceans.

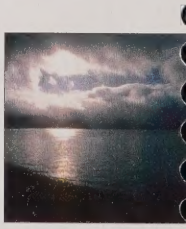
PROJECT TITLES:
Impact of Variability and Climate Change on Carbon Sequestration in a Boreal Forest
Objective: Characterise variability in boreal forest carbon and water budgets and understand factors of carbon sequestration over several annual cycle

Science Advisory on Climate Change
Objective: Provide information on variou adverse atmospheric effects and advise on the energy implications of such processes.

Estimation of Terrestrial CO_2 Sources and Sinks in Canada
Objective: Data acquisition to improve modelling of biospheric–atmospheric CO exchange processes.







Program of Energy Research and Development at Environment Canada

1999–2001

A Two-Year Review

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June 2001

Overview

Environment Canada has been an active participant in the federal Program of Energy Research and Development (PERD) since 1977. Together with other federal departments, universities, and industry sectors, EC through PERD has contributed to finding solutions for sustainable energy development for the benefit of Canadians.

EC manages a diverse research and development portfolio funded by PERD, leading on the delivery of environmental science and technology initiatives specific to energy. EC leads in a number of areas such as: flaring, groundwater and soil remediation, particulate matter, sustainable community development, bioprocesses, and the enhancement of greenhouse gas sinks. In addition, EC managers have contributed their expertise to a myriad of other initiatives ranging from weather prediction–to cumulative effects of toxics–to alternative energy technologies. This participation has led to the advancement and sharing of knowledge in technologies, and will also contribute to ensuring sustainable development in northern and frontier regions.

Science and technology efforts under PERD have been world class, supporting decision-making, policy development, and regulatory activities; contributing to the development of national standards and guidelines; supporting public safety; and environmental needs.

Through PERD, EC has developed a high level of expertise which has led to the advancement of knowledge in a number of Business Line priority areas allowing for timely advice on emerging and existing issues.

This report highlights Environment Canada's involvement in PERD from 1999–2001, during which time PERD was restructured to follow a results-based management framework. Section 1 highlights how EC's energy research and development activities jointly benefit both the Department and PERD mandates. Section 2 outlines ECs current involvement in PERD at the project level with emphasis on successful partnerships, leveraging, and technology transfer efforts.

Survol

Environnement Canada (EC) est un participant actif au Programme de recherche et de développement énergétiques (PRDE) du gouvernement fédéral depuis 1977. Grâce à sa collaboration avec d'autres ministères fédéraux, des universités et des secteurs de l'industrie, la recherche menée à EC, laquelle est financée par le PRDE, a contribué à mieux comprendre les effets sur l'environnement découlant de l'utilisation des sources d'énergie traditionnelles et de la découverte de nouvelles sources d'énergie renouvelables.

EC mène divers projets de recherche et de développement qui sont financés par le PRDE, et le ministère est un chef de file dans plusieurs secteurs de recherche tels que le brûlage à la torche, la restauration des eaux souterraines et des sols, les matières particulaires, le développement durable des collectivités, les bioprocédés et l'amélioration des puits de gaz à effet de serre. Les gestionnaires d'EC ont apporté leur expertise à une multitude d'initiatives allant de la prévision météorologique à l'effet cumulatif des substances toxiques et aux technologies d'énergie innovatrices résultant en l'établissement de réseaux scientifiques et de réseaux d'échange de pratiques.

Les efforts de recherche et de développement qu'a déployés EC dans le cadre du PRDE ont été reconnus mondialement. Ils ont contribué à de saines prises de décisions en matière de politiques et de règlements et à l'élaboration de normes et de recommandations nationales, tout en répondant à des besoins en matière de sécurité et d'environnement.

Grâce au PRDE, EC a acquis une compétence de haut niveau, ce qui lui a permis d'approfondir ses connaissances dans plusieurs secteurs d'activités prioritaires, d'offrir des conseils opportuns sur des enjeux nouveaux ou existants.

Ce rapport souligne la participation d'EC au PRDE de 1999 à 2001, alors que le programme faisait l'objet d'une restructuration selon un cadre de gestion axée sur les résultats. La section 1 contient un court résumé des avantages dont le ministère et le PRDE ont pu bénéficier à la suite de la participation des deux parties au PRDE. La section 2 décrit la participation actuelle d'EC au PRDE aux projets et souligne ses réussites en ce qui a trait aux partenariats et à leur effet levier ainsi qu'au transfert de technologie.

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Acronyms

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AAFC .....Agriculture and Agri-Food Canada
AAQD .....Analysis and Air Quality Division
ACSYS .....Arctic Climate System Study
ADM .....Assistant Deputy Minister
AES .....Atmospheric Environment Service
AFTER.....Advanced Fuels and Transportation Emissions Reduction
ArcInfo.....Software in field of environmental mapping for analysis and modelling
As .....Arsenic
ASHRAE.....American Society of Heating, Refrigerating, and Air Engineers
ATES.....Aquifer Thermal Energy Storage
ATOFLAMS.....Atmospheric Time-of-Flight Laser Ablation Mass Spectrometry
BEPS.....Boreal Ecosystems Productivity Simulator
BERMS.....Boreal Ecosystem Research and Monitoring Sites
BIOCAP.....Biosphere Implications for CO_2 Policy in Canada
CAM .....Canadian Aerosol Module
CANMET .....Canada Centre for Mineral and Energy Technology
CAPP.....Canadian Association of Petroleum Producers
CBM .....Coalbed Methane
CCAF–TEAM .....Climate Change Action Fund, Technology for Early Action Measures
CCTEAF .....Climate Change Technology Early Action Fund
CCG .....Canadian Coast Guard
CCIES .....Climate Change Impacts on the Energy Sector
CCME.....Canadian Council of Ministers of the Environment
C-CORE .....Centre for Cold Ocean Research Engineering
CCRP .....Climate Change Research Program
CCRS .....Canada Centre for Remote Sensing
CD .....Companion Document
CEPA.....Canadian Environmental Protection Act
CES .....Community Energy Systems
CETC.....CANMET Energy Technology Centre
CH_4/CO_2 .....Methane/Carbon Dioxide
CHELASOL .....Chelation/Solvent Extraction Process
CIS .....Canadian Ice Service
CLASS model.....Canadian Land Surface Scheme model
CLIVAR .....Climate Variability and Prediction Program
CMHC.....Canada Mortgage and Housing Corporation
CNOPB.....Canada–-Newfoundland Offshore Petroleum Board
CNSOPB .....Canada–-Nova Scotia Offshore Petroleum Board
CO .....Carbon Monoxide
CO_2.....Carbon Dioxide
COFE .....Characterization of Canadian Fuels and their Emissions
CPPI.....The Canadian Petroleum Products Institute
Cr.....Chromium
CRCM.....Canadian Regional Climate Model
CSA .....Canadian Standards Association
DFO.....Department of Fisheries and Oceans
DND.....Department of National Defence
DRECT .....Demonstration of Resource and Energy Conservation Technology
EAE .....Environmentally Acceptable Endpoints

Acronyms

EBAD.....Environmental Biotechnology Applications Division
EC .....Environment Canada
ECES .....Energy Conservation through Energy Storage
EED.....Emergencies Engineering Division
EGGS.....Enhancement of GHG sinks POL
EPF .....Energy Priority Framework
ERAC .....Environmental Research Advisory Council
ERS–2.....European Remote Sensing Satellites
ETB .....Energy Technology Branch
ETC .....Environmental Technology Centre
EV.....Electric vehicle
FCM.....Federation of Canadian Municipalities
FIRE III .....First ISCCP Regional Experiment -III (1994-1999)
Fluxnet–Canada CO_2
flux network .....A national university network integrating worldwide CO_2 flux measurements.
FRI.....Flaring Research Initiative
GASREP .....Groundwater and Soil Remediation Environmental Program
GCMs .....Global Climate Models
GEM .....Global Environmental Model
GEWEX.....Global Energy and Water Cycle Experiment
GHG .....Greenhouse Gases
GIS .....Geographic Information System
GRI/DOE .....Gas Research Institute/Department of Energy
GSC.....Geological Survey of Canada
GSM .....Global System for Mobile Communications
HAPs .....Hazardous Air Pollutants
HC .....Health Canada
HEV.....Hybrid Electric Vehicle
Hg.....Mercury
HMDC .....Hibernia Management Development Corporation
IC.....Industry Canada
IEA.....International Energy Agency
IEA-ECES .....International Energy Agency Implementing Agreement on Energy Conservation through Energy Storage
IGBP.....International Geosphere-Biosphere Program
IGCC .....Integrated Gasification Combined Cycle
INAC.....Indian and Northern Affairs Canada
IPCC.....Intergovernmental Panel on Climate Change
ISCCP .....International Satellite Cloud Climatology Project
ISWM.....Integrated Solid Waste Management
JGR .....Journal of Geophysical Research
k.....thousand
LFG .....Landfill gas
LICOR .....LI-COR Biosciences-designs and manufactures instrument systems for plant biology, biotechnology, and environmental research
M .....Million (i.e., $1x10^6$)
MAGS.....Mackenzie GEWEX Study
MAM.....Multispectral Atmospheric Mapping
MAP.....Microwave-Assisted Processes
MC2.....Mesoscale Compressible Community model
MIROS .....Microwave Remote Sensor for the Ocean Surface
MOU.....Memorandum of Understanding
MSC .....Meteorological Service of Canada
Mt .....megatonnes
MTS.....Marine Transport and Safety
NARCM .....Northern Aerosol Regional Climate Model

NEB	National Energy Board
Ni	Nickel
NOMAD	Navy Oceanographic Meteorological Automatic Device
NO_x	nitrogen oxides
NRBS	Northern River Basins Study
NRC	National Research Council of Canada
NRCan	Natural Resources Canada
NRCM	Northern Aerosol Regional Climate Model
NREI	Northern Rivers Ecosystem Initiative
NSERC	Natural Sciences and Engineering Research Council of Canada
NSIDC	National Snow and Ice Data Centre
NWRI	National Water Research Institute
O_2	Oxygen
ODS	ozone-depleting substances
OECD	Organisation for Economic Cooperation and Development
OEF	Offshore Environmental Factors
OERD	Office of Energy Research and Development
PAC	Polycyclic Aromatic Compounds
PAHs	Polycyclic Aromatic Hydrocarbons
PCBs	Polychlorinated Biphenyls
PCP	Partners for Climate Protection
PERD	Program of Energy Research and Development
PM	Particulate Matter
PMG technology	Permanent Magnetic Generator technology
POL	Program at the Objective Level
PTAC	Petroleum Technology Alliance Canada
PWGSC	Public Works and Government Services Canada
R&D	research and development
RADARSAT	Radar Satellite
RCM	Regional Climate Modelling
RSI	Radarsat International
RTDF	Remediation Technology Development Forum
RWDI	Rowan Williams Davies and Irwin Inc.
S&T	Science and Technology
SAIC	Science Applications International Corporation
SAR	Synthetic Aperture Radar
SETAC	Society of Environmental Toxicology and Chemistry
SHEBA	Surface Heat Budget of the Arctic Ocean
SNTHERM	Snow Thermal model (A process driven, one dimensional energy and mass-balanced model to calculate snow melt and other snowpack fluxes)
SO_x	sulphur oxides
SWS-2	Storm Wave Study -2
t	tonne (metric)
TC	Transport Canada
TES	Thermal Energy Storage
TIE	Toxicity Identification Evaluation
TNR	Toronto-Niagara Region
TSRI	Toxic Substance Research Initiative
USDOE	United States Department of Energy
USEPA	United States Environmental Protection Agency
UTES	Underground Thermal Energy Storage
VOC	Volatile Organic Compounds
WATFLOOD	Waterloo Flood Forecasting model
WCRP	World Climate Research Programme
WGCCM	Working Group on Coupled Climate Modelling

Introduction

The Program of Energy Research and Development at Environment Canada

For more than twenty years, Environment Canada (EC), through its participation in the federal Program of Energy Research and Development (PERD), has contributed world class science and technology for the safe, environmentally sound and economically viable development of the energy sector in Canada, while simultaneously advancing Environment Canada's mission to make sustainable development a reality for Canadians. PERD is currently a $57.6M interdepartmental program coordinated and funded by Natural Resources Canada (NRCan). The success of EC's participation in PERD is attributed in part to the many partnerships developed with other federal departments, universities, and industry sectors. Environment Canada receives a PERD budget of $5.3M, which is the second highest allocation of the eleven participating departments and agencies next to NRCan (Figure 1).

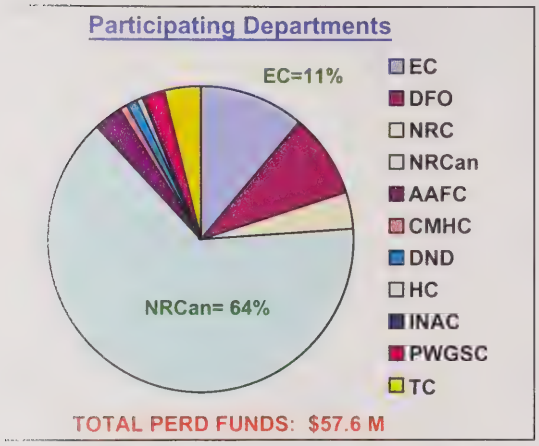


Figure 1 PERD Funding Allocation 2000–2001

Why EC Participates

PERD is the only federal energy research and development program that focuses specifically on Canadian energy issues and their impact. Environment Canada participates in PERD to advance objectives in an environmentally sound manner, delivering on the mission of the department by helping Canadians live and prosper in an environment that is protected and conserved.

PERD promotes collaboration which ensures holistic solutions to energy research and development. An example of this type of collaboration within science-based Departments is the 'Particulate' objective under PERD. This project brings together experts from different departments to address each aspect of the issue, from emissions characterization to atmospheric measurement and modelling, to acute and chronic health effects. The integration of these activities under one POL provides scientific as well as financial leverage. Researchers work in parallel towards common solutions specifically by reducing adverse health effects and improving air quality.

Environment Canada's participation in such program as PERD provides the information needed to identify and respond to existing and emerging environmental challenges. Moreover, these activities serve as a basis for the formulation of environmental policies needed to achieve sustainable development. Finally, PERD activities support the development of new environmental technologies to prevent and remediate environmental pollution.

Managing for Results

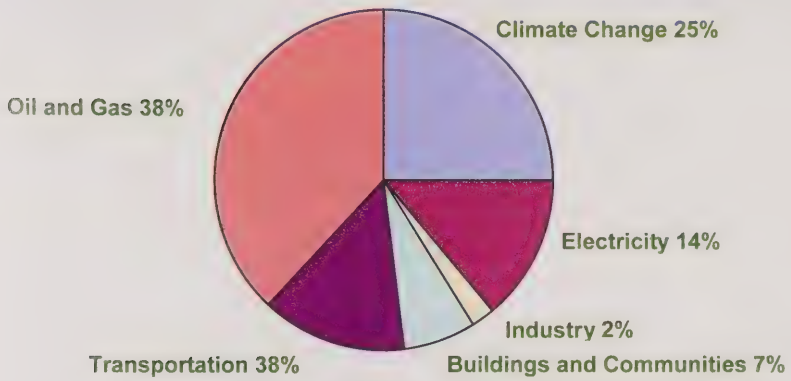
Like many other programs within the federal government, PERD has moved from an activity-based program to a results-based management (RBM) framework. This structure helps PERD be more flexible and responsive to Canada's dynamic energy priorities to ensure a sustainable future.

In 1999, the Assistant Deputy Minister (ADM) of NRCan's Energy Sector recognized the need to restructure the program to form a better link between energy sector policies and science and technology investments. The approach incorporated performance measurement and evaluation within the framework, essential to more effectively monitor progress and increase the level of accountability to deliver results. In addition, the RBM structure lends itself to increased interdepartmental collaboration specifically because the projects are grouped under common areas within the Program at the Objective Level (POL).

The RBM logic model links POL outputs to higher level outcomes and longer term impacts. An evaluation process is built into this model in which each year one quarter of the POLs in the overall program are reviewed. In this evaluation, external reviewers determine if the outputs have been achieved and if any outcomes are attributed to those achievements. Once the evaluation has been performed, a second review attempts to shape the framework of priorities for the next term of POLs. This review process determines the allocation of funds, as well as the creation, termination, expansion, and merging of POLs that suit the current Energy Priority Framework (EPF).

The EPF, developed by the Energy Sector of NRCan, summarizes the current energy priorities facing Canada. In response to these priorities, the S&T Companion Document (CD) supplements the EPF by defining six strategic intents that describe the broad directions of NRCan's non-nuclear energy S&T activities. Strategic intents are divided according to major priorities called strategic directions, with each strategic direction having one or more long-term objectives. Environment Canada participates in projects under all six Strategic Intents. Figure 2 presents the relative importance of each Strategic Intent within Environment Canada's overall participation in the PERD program.

Strategic Intent 1: Diversifying Canada's Oil and Gas
Strategic Intent 2: Cleaner Transportation for the Future
Strategic Intent 3: Energy-efficient Buildings and Communities
Strategic Intent 4: Energy-efficient Industry
Strategic Intent 5: Canada's Electricity Infrastructure
Strategic Intent 6: Climate Change



e 2 Environment Canada's Level of Participation in PERD Strategic Intents

nment Canada is the lead department for six of the POLs which include programs on g, groundwater and soil remediation, particulate matter, sustainable community lopment, bioprocesses, and the enhancement of greenhouse gas sinks.

D and Environment Canada's Business Lines

nment Canada is a key player in the PERD program, leading the delivery of environmental e and technology specific to energy issues with quite a diverse portfolio. Environment a manages 47 PERD projects, contributing to 18 of the 38 program objectives under . The Department reaps direct benefits from PERD involvement, as all of the projects ng PERD funds contribute to at least one of EC's three science Business Lines (i.e., Clean ronment, Nature, and Weather and Environmental Predictions). Figure 3 depicts the entage of PERD dollars that contribute to EC's three key business lines.

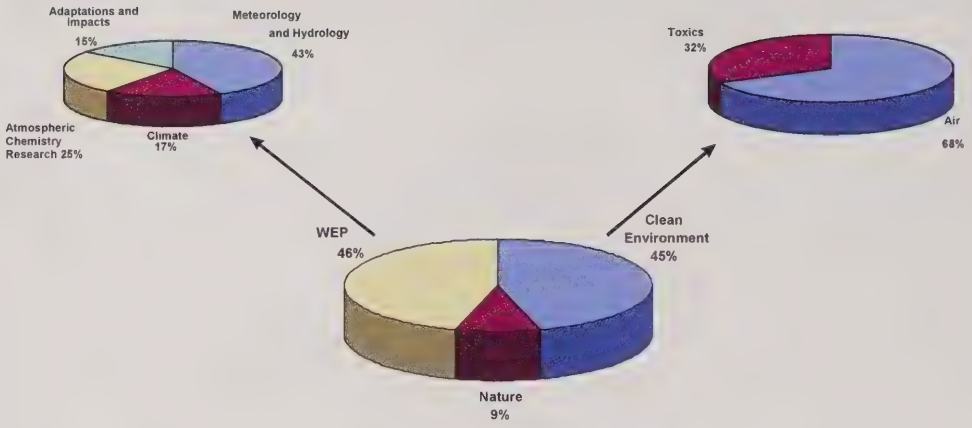


Figure 3 Breakdown of PERD Contribution to EC's Three Key Business Lines

Clean Environment Business Line

"The federal government has clearly committed to maintaining a healthy economy while protecting the environment and human health. Increasingly, the public looks to Environment Canada for answers on how to achieve this goal. More than ever, we need to understand the risks to the environment, human health, and their interactions and to find solutions to minimize the risks. This need sets the direction for the R&D priorities under the Clean Environment business line" (July 2000–Clean Environment Research Agenda 2000-2005).

PERD complements the Clean Environment Business Line research and development agenda to help meet the priorities and obligations of the department in protecting Canadians from domestic and global sources of pollution. Approximately 45% of Environment Canada's PERD dollars support the Clean Environment R&D Agenda. Of that, close to 70% is spent on Air Issues which encompass Climate Change, Air Quality, Acid Rain, Hazardous Air Pollutants, and Stratospheric Ozone. The remainder is currently dedicated to Toxics. These contributions specifically address the requirements of the Canadian Environmental Protection Act, as the Minister of Environment has the responsiblility to: "*establish and maintain a system for monitoring environmental quality; conduct research and studies relating to the nature, transportation, dispersion, effects, control and abatement of environmental pollution on environmental quality; conduct research relating to disturbances of ecosystems by human activity, to changes in the normal geochemical cycling of toxic substances that are naturally present in the environment, and to detection of damage to ecosystems*" (July 2000–Clean Environment Research Agenda 2000-2005).

Clean Environment is divided into two long-term results: air result, and toxics result. The following activities are currently underway through PERD:

Table 1
PERD Activities Linked to the Clean Environment Business Line

Areas	Sub-Groups	PERD Activities
Air Results	Climate Change	• CO_2 Capture and Storage through Coal Bed Methane Production • Natural sinks • Renewable energy • Reduction of GHG emissions primarily due to flaring • Ethanol characterization and emission testing
	Air Quality	• Reduction of emissions due to flaring • Optimization of diesel performance • Source apportionment studies for stationary and mobile sources • Technologies for particulate measurements
	Acid Rain	• NOx sensor technology for vehicles • Integrated Gasification Combined Cycle for Cleaner coal use
Toxics Results		• Collaborative Particulate research with Health Canada and NRCan • Mercury research in coal-fired power plants • PAH identification from flares • Identification of Acid Aldehyde presence in Ethanol emissions • Preparedness and response on oil and chemical spills (Ethers) • Remediation technology development for contaminated sites • Endpoint development of contaminated soils to feed into CWS for Petroleum Hydrocarbons

Weather and Environmental Prediction (WEP) Business Line

"Canadians are affected by weather and environmental conditions such as tornadoes, winter storms, floods, droughts, lake water levels, aircraft turbulence, and road icing. These conditions affect the health and safety of Canadians, their businesses, the economy, and the environment. The WEP business line supports sustainable development by providing: a) warnings for health, safety, adaptation, and reduced economic loss; b) weather and environmental forecasts and information for effective decision-making (health, economic efficiency, and environmental quality); and, c) knowledge and understanding for environmental policies based on sound science." (WEP Business Plan Overview, July 2000– WEP Research Agenda 2000-2005).

PERD participation helps advance these WEP goals in a significant way. Largely conducted by the Meteorological Service of Canada, the work in many cases contributes to ensuring the safe and efficient conduct of energy-related activities in Canada (particularly in the offshore areas). Several activities also support the provision of knowledge for decision-making in areas such as climate and air quality. New projects are being initiated to address new PERD objectives in areas such as climate change impacts.

PERD activities linked to WEP are diverse, being conducted in several POLs, including Climate Impacts (largest EC participation in terms of funding), Offshore Environment, Greenhouse Gases, Transportation, Renewable Resources, Marine Transport, and Transport Efficiency. Approximately 46% of Environment Canada's PERD dollars complements the Weather and Environmental Prediction Business Line. Of that portion, 43% is dedicated to Meteorology and Hydrology, 25% to Atmospheric Chemistry Research, 17% to Climate, and the remainder to Impacts and Adaptations. Table 2 illustrates the strong PERD–WEP connection.

Table 2
PERD Activities linked to the Weather and Environmental Prediction Business Line

Areas	Sub-Groups	PERD Activities
Meteorology and Hydrology	Numerical Weather Prediction Data Assimilation Environmental Prediction	• improved offshore design criteria (winds and waves) • improved data assimilation methods for atmosphere/ocean wave models • ice modelling for offshore operations • operational iceberg detection • resource assessment of wind and solar energy potential • Gulf of St. Lawrence route management in ice conditions
Climate	Climate Monitoring and Data Interpretation Climate Processes and Earth Observation Climate Modelling and Analysis	• regional modelling and climate scenarios for the Gulf of St. Lawrence • FIRE III and SHEBA (arctic cloud processes) • climate/sea ice processes using satellite microwave • carbon budgets of Canadian forests
Atmospheric Chemistry Research	Stratospheric Ozone and Space Research GHGs, Aerosols, and Surface Radiation Research Acidifying Deposition and Oxidants Research Particulate Matter/Aerosol Research Hazardous Air Pollutants	• specification of natural versus anthropogenic aerosols • characterization of particulate emissions in the transportation sector • GHG emission reduction
Adaptations and Impacts	Impacts and Adaptation Science Impacts and Integrated Assessment	• climate change effects on design of offshore structures • climate change effects on hydrology and on aquatics • climate change and energy in the Toronto/Niagara region • natural versus anthropogenic impacts

Nature Business Line

The objective of this business line is to…*"conserve biological diversity in healthy ecosystems, to reduce human impacts on the health of ecosystems, and to conserve and restore priority ecosystems" (EC website– www.ec.gc.ca/introec/mngmtframe/shap6_e.htm#nature).*

The effects of energy production and use are contributing to the reduction of natural habitats. Specific energy-related threats to ecosystems include air and water pollution, and climate change.

Environment Canada contributes 9% of it's $5.3M PERD allotment to Nature Business Line activities. This contribution specifically aims at understanding and reducing human impacts on the health of ecosystems. The following research directly contributes to the nature research agenda.

Table 3
PERD Activities linked to the Nature Business Line

Sub-Groups	PERD Activities
Understanding and reducing human impacts on the health of ecosystems	• effects of climate change on northern hydrologic cycles • effects on carbon sequestration in boreal forests • fate and behaviour of hydrocarbons in wetlands (Northern River Basin impacts study)

PERD's contribution to the Nature Business Line R&D Agenda has been small in comparison to the other two business lines; however, there are opportunities within PERD to help advance its R&D Agenda. For example, more emphasis has been placed recently on Northern Energy Development, and associated research requirements on cumulative effects.

Conclusion–Future Opportunities

Environment Canada is a strong participant in the PERD program, showing federal leadership in sustainable energy R&D. In this setting, needs and opportunities for future work are numerous. The effects of energy development on northern and frontier regions still needs to be addressed. The changing climate also needs to be taken into consideration during energy development to

enable increased sustainability over time.

Environment Canada is obligated to protect the environment. By participating in initial research and development, many pollutant releases can be avoided by promoting and developing technologies that are low emitters and conserve energy. Environment Canada also has a mandate to protect Canadian lives and property. With respect to energy sector activities, this includes clean coal technologies, hydrogen research, combined heat and power alternatives, alternative energy, carbon sinks, climate effects and sustainable Northern oil and gas development. Through PERD, collaboration with other federal departments, industry, universities, the provinces and the territories helps ensure that individual efforts have sufficient leverage to make a difference in areas well linked to ECs Business Line priorities.

Profiles by Strategic Intent

The following section describes the programs at the objective level (POLs) in which EC participates and gives a brief overview of the EC projects involved in those POLs.

Strategic Intent 1—Oil and Gas Sector

Strategic Intent 1 is to fulfill federal government responsibilities while maximizing economic benefits and reducing environmental consequences from the expansion and diversification of Canada's oil and gas production.

Strategic Intent 1 · Strategic Direction 2

Strategic Direction 2 provides S&T to extend and diversify Canada's oil and gas production from offshore and northern regions through the development of the science and technology needed for standards and regulations, and to reduce costs and mitigate environmental and safety concerns.

Strategic Intent 1 · Strategic Direction 2 · Objective 1.2.1

Offshore Environmental Factors (OEF) for Regulatory, Design, Safety, and Economic Purposes. (Multiplayer)

POL 1.2.1
This POL is a group of coordinated research initiatives from various federal departments that involve the identification and development of various climatologies and operational methods to describe, hindcast, and forecast environmental factors relating to loadings and operational limits for oil and gas exploration and production purposes off Canada's East Coast. Activities within the program focus on Winds and Waves, Ocean Currents and Circulation, Sea Ice and Icebergs, Ice-Structure Interaction, Seabed Stability, and Basin Assessment issues. The research helps fulfill government departmental mandates in support of energy development and sustainable development; provides the ability to make timely and economical engineering decisions and regulatory approvals; and helps ensure human safety and environmentally safe oil and gas operations.

The research is a coordinated effort by federal laboratories from EC, DFO, NRC, and NRCan, as well as those from Canadian and international universities, industry, private contractors, and federal regulators, such as the Canadian Association of Petroleum Producers (CAPP), the National Energy Board (NEB), and two Offshore Regulatory Boards [Canada-Newfoundland Offshore Petroleum Board (CNOPB) and Canada-Nova Scotia Offshore Petroleum Board (CNSOPB)].

The following activities are covered under POL 1.2.1:

- Wind- and Wave-hindcasting and Forecasting (EC participation)
- Sea Ice and Iceberg Detection and Forecasting (EC participation)
- Ocean Current Measurements and Circulation Modelling
- Ice-structure Interaction Research and Standard Setting
- Seabed Stability Research and Development
- Basin Assessment Research

Profiles by Strategic Intent

Oil and Gas Sector

Offshore Environmental Factors

POL 1.2.1 is scheduled to span 2000–2001 to 2001–2002. Average total funding per year for this POL is $10.1M. The proposed average PERD funding per year was $2.782M, for fiscal years 2000–2002. PERD funds were divided amongst the departments involved in this POL (see Table 4). For this POL, the average leverage quotient of total resources to PERD resources was 3.6.

Table 4
Percentage of PERD Funds for POL 1.2.1 Allocated to Each of the Departments

Department	Percentage of Funds (%)	
	2000–2001	2001–2002
NRCan	32.4	34.6
EC	23.7	24.3
NRC	20.7	21.3
DFO	18.2	19.8
POL Evaluation	5.0	0.0

Environment Canada Projects for POL 1.2.1

Operational Ice Modelling

Project Manager: Tom Carrières

Overview
This ongoing project addresses the needs of offshore energy production in ice environments. It began in 1987 with primary focus on the Beaufort Sea. The current focus is on Canada's East Coast where icebergs are a main concern as well as sea ice, to a lesser extent. This project is closely coordinated with a PERD-funded project on coupled ice-ocean modelling managed at the Bedford Institute of Oceanography. There are also connections with the offshore energy industry and their consultants, and with the International Ice Patrol, National Research Council, and McGill University.

Objectives
The goal is to optimize sea ice and iceberg analysis and forecast the capability of the Canadian Ice Service (CIS) as well as to deliver enhanced analysis and forecasting to the offshore energy industry. The benefits to Environment Canada are that CIS can issue more accurate and relevant products.

Outputs and Methodology
The objectives have been and will be achieved through accelerated ice modelling development and operational implementation. There is also some field activity related to improving model parameterizations and model validation. The success of the project can best be measured by steadily improving model performance indicators, such as ice edge location or iceberg positions.

Funding
The average resources allocated for this project per fiscal year were $329K (1999–2000; 2000–2001). An average 70.4% of these resources came from PERD funds, the rest came from other sources (A-Base, industry). The average leverage quotient of total resources to PERD resources for this project was 1.4.

Profiles by Strategic Intent

Oil and Gas Sector

Offshore Environmental Factors

Detection of Icebergs

Operational Detection of Icebergs from Remotely Sensed Data

Project Manager: Dean Flett

Overview

This project was initiated and received its first funding in 1999–2000 and does not stem from a previous PERD project. It is primarily a stand-alone project and is not part of a bigger project or program; however, the objectives of the project link with the larger agency goals of the CIS to improve and enhance its ice and iceberg monitoring program. In addition, this project is also linked to another PERD project managed by the CIS (Tom Carrières) under the Marine Transportation and Safety POL entitled *Prediction of Small Glacial Mass Distributions*. That project focuses on the needs of shuttle tankers by providing analyses and forecasts of "bergy" bits (small icebergs that have broken away from a larger iceberg) and surface currents. RADARSAT data will be acquired in conjunction with the collection of validation data to support the modelling component of that project to augment the validation of data for this project.

Objectives

The first objective of this project is to assess the capabilities and limitations (i.e., thresholds) of space-borne SAR (Synthetic Aperture Radar) for detecting icebergs. The second main objective is to develop tools and techniques to extract (both manually and using automated computer-assisted means) iceberg positional data from space-borne SAR and add it as an additional data input to the present CIS iceberg system. This will enhance the coverage capability of the iceberg monitoring system and ensure more complete, accurate, and timely iceberg population data and improve ice services provided to the offshore oil and gas industry.

This project fits directly into the OEF POL specifically under the "Sea Ice and Icebergs" component of the POL 1.2.1. Based on concerns that were expressed in industry/regulator surveys and in a client workshop organized by the CIS (Tom Carrières) held in St. John's, NF, in November 1999, primary areas of interest focussed on east coast icebergs, sea ice, and ocean currents.

As part of its mandate, the CIS presently maintains an iceberg monitoring and prediction service in coordination with the International Ice Patrol (U.S. Coast Guard). The CIS routinely acquires iceberg data from aircraft reconnaissance, ship, and shore reports. Coverage, however, is far from comprehensive and "nowcast" techniques must be used to document iceberg populations over large areas. Observation data input to the system is through alphanumeric iceberg reporting and messaging only. The CIS receives RADARSAT SAR imagery to support its sea ice service, and icebergs are visually evident in these data. Currently, the RADARSAT is an untapped additional data source for iceberg information. By developing the capability to expand the use of remotely sensed data, particularly RADARSAT SAR data, to detect and monitor icebergs off Canada's East Coast, the CIS will improve its ability to issue more complete, timely, and accurate iceberg warnings and forecasts. Since icebergs are a continuing hazard for marine activities, this meets the Environment Canada objective to minimize risks to life and property. Improved iceberg analyses and forecasts also meet the PERD objective to enhance the predictive capability of marine environmental parameters that have a direct bearing on human safety and sound operations.

Outputs and Methodology
Specific outputs/deliverables of the project and their associated performance indicators are outlined:

- *Refinement of C-CORE Target Detection Algorithm*—The goal of the target detection algorithm and software developed as part of this project will be to achieve the lowest false alarm rate possible on potential iceberg detection. Although difficult to estimate at present, a goal of less than 15% false alarms is suggested.

- *Assessment of advanced target detection algorithms*—The assessment of alternative target detection algorithms (commercial or research) will be measured against the results achieved using the C-CORE algorithm.

- *Statistical Analysis to determine detection thresholds and probability curves as a function of sea state and environmental conditions*—The goal of this output is to develop a set of curves characterizing the detection thresholds and the probabilities of detection, given various environmental (i.e., wind) conditions in order to refine the detection algorithms.

- *Development of prototype tools for extracting iceberg data from SAR*—Appropriate tools ands systems to minimize additional operator/analyst interaction while balancing added value and information will be developed to measure and evaluate this output.

- *Establishment of prototype methods to integrate RADARSAT–extracted data with conventionally acquired iceberg data*—Similar to the previous output, the success of this output will be measured in terms of the simplicity of the methods and operational procedures developed to maximize the usefulness of the SAR-derived iceberg information for iceberg monitoring.

- *Establishment of full CIS operational capability to detect icebergs from space-borne SAR*—The complete end-to-end data acquisition and processing chain will be assessed to ensure that the coverage capability of the iceberg monitoring system has been enhanced and that more complete, accurate, and timely iceberg population data and improved ice services are provided to the offshore oil and gas industry.

These outputs will be achieved using a mix of technology development; field and lab trials, analysis, and assessment; and through the development and refinement of procedures and data flow to maximize the operational use of iceberg data and information extracted from space-borne SAR data. Field programs carried out since the 1999 iceberg season off Canada's East Coast will continue to be supported to further refine iceberg detection thresholds and probability curves, as input to the automated target detection software development. Post-analysis and evaluation of algorithms and their results will be carried out in the CIS Image Lab as well as by C-CORE (and other potential end users, e.g., Provincial Airlines). Near real-time demonstrations processing RADARSAT data will be delivered to the CIS through the C-CORE software and will provide derived iceberg information products to support offshore ice management. Assessment of the tools, systems, and operational methods and techniques will be done at CIS by having the operational iceberg analysts and forecasters evaluate and provide feedback on the best procedures for operational work flow.

Funding
The average resources allocated for this project per fiscal year were $50k (1999–2000; 2000–2001). An average 50% of these resources came from PERD funds, the rest of the came from other sources (A-Base, industry). The average leverage quotient of total resources to PERD resources for this project was 2.0.

Profiles by Strategic Intent

Oil and Gas Sector

Offshore Environmental Factors

Validation of Wind and Wave Measurements

Validation of Buoy and Platform Wind and Wave Measurements

Project Manager: Val Swail

Overview

This work was initiated in 1997 and does not stem from a previous PERD project. It contributes to the overall research efforts on wind and wave hindcasting and forecasting coordinated through the Canadian National Waves Committee, and in particular to the PERD wind and wave project (*Offshore Wind and Wave Design Criteria)* to reduce the uncertainty in design criteria.

Objectives

The goals of the program were to determine: (1) the validity of the Microwave Remote Sensor for the Ocean Surface (MIROS) wave system as a replacement in the regulatory requirements for conventional wave buoy measurements; and (2) the reliability of new buoy wind and wave measurement technologies in severe storms. The results will contribute to reducing the uncertainty in design criteria estimates for wind and waves, and to increasing the reliability of wind and wave forecasts, thus contributing to improving human safety and environmentally safe operations.

The results will be of great importance to EC, where the wind and wave data are used in hindcast studies for development of design criteria and operational wave forecast programs, and also, in studies dealing with assessment of remote sensing technologies, air-sea fluxes, and climate variability.

Outputs and Methodology

1. Report and presentation of validation results to HMDC, NEB, CNOPB. Goal: Evaluation of suitability and reliability of MIROS wave radar on HMDC platform—March 2000. Approach: Compare MIROS data with SWS-2 directional wave rider buoy located nearby.

2. Technical report on validation results to scientific community, Boards, industry. Goal: Evaluation of suitability and reliability of buoy wind and wave measurements in extreme sea states—March 2001. Approach: Compare SWS-2 NOMAD buoy waves with directional wave rider, winds with calibrated wind observations from BIO research vessel HUDSON, model results from NRC.

3. Revised wind and wave payloads and processing algorithms in operational buoy program. Goal: Reduce uncertainty in buoy wind and wave observations in extreme storms —March 2002. Approach: In cooperation with Canadian and international buoy specialists, implement changes to instrumentation and processing based on technical validation, where appropriate and feasible.

Funding

The average resources allocated for this project per fiscal year were $212k (1999–2000; 2000–2001). An average 38.7% of these resources came from PERD funds, the rest came from other sources (A-Base, industry, others). The average leverage quotient of total resources to PERD resources for this project was 2.6.

Offshore Wind and Wave Design Criteria

Project Manager: Val Swail

Overview
This project was initiated in 1998 and does not stem from a previous PERD project. Work done in this project benefits from results on wind and wave observation assessment and development in PERD project *Validation of Buoy and Platform Wind and Wave Measurements*, and contributes wind and wave results (40-year hindcast) to PERD project *Climate Change and Offshore Design Criteria*.

Objectives
This project develops methodologies to reliably determine offshore wind and wave design criteria, for application in the establishment of metocean (meteorology and oceanology) design criteria, with particular emphasis on capital and operating cost reductions while maintaining responsible levels of safety.

This project responds to the three lines of the EC Business Plan and the Sustainable Development Strategy, specifically "reducing risks to human health and the environment" and "minimizing risks to life and property". The research in this project is the primary work done at EC in describing the marine climate, its variability, and trends.

Outputs and Methodology
- Completion of hindcast, data available to industry and boards upon request. Goal: 40 years continuous wind-wave hindcast—March 2000. Approach: Apply existing hindcast models and procedures, including intensive kinematic wind analysis, and tropical storm analysis.

- Delivery to Boards as addendum to Physical Environmental Guidelines, to industry. Goal: Wind-wave design and operating criteria based on continuous hindcast—March 2001. Approach: Validation of hindcast results compared to measurements; extremal statistical analysis and spatial mapping, into populations of tropical and extra-tropical origin.

- Model and methodology to reduce uncertainty in highest waves hindcast (e.g., Hallowe'en storm by 50%). Goal: Revised wind and wave models and hindcast procedures—March 2002. Approach: Implementation of results into wind and wave measurement and model deficiencies, particularly in high waves.

- Completion of revised, extended hindcast, data available to industry and boards upon request. Goal: 6-year continuous wind-wave hindcast—March 2003. Approach: Apply revised wind and wave models and hindcast procedures to extend hindcast, with 1-year overlap.

- Delivery to Boards as revised addendum to Physical Environmental Guidelines, and to industry. Goal: Revised wind-wave design criteria based on additional years and revised methodologies—March 2004. Approach: Extremal statistical analysis of hindcast results.

Funding
The average resources allocated for this project per fiscal year were $475.5k (1999–2000; 2000–2001). An average 41.6% of these resources came from PERD funds, the rest came from other sources (A-Base, industry). The average leverage quotient of total resources to PERD resources for this project was 2.4.

Profiles by Strategic Intent

Oil and Gas Sector

Offshore Environmental Factors

Coupled Atmosphere–Ocean Wave Models

Data Assimilation into Coupled Atmosphere–Ocean Wave Models

Project Manager: Laurence Wilson

Overview

This project combined two PERD projects (1997), one dealing with coupled modelling research and development, and the other emphasizing the use of newly available remotely sensed observations for the analysis and monitoring of marine wind and waves. The overall project involves the data providers (e.g., RSI for RADARSAT data and CCRS), along with the government atmospheric modelling community (EC), and the government–ocean modelling community (DFO). Most of the work on the overall project is carried out within the government and by contract to government research labs; however, there is also frequent consultation with the international wave modelling and data assimilation research communities.

Objectives

The ultimate goal is to develop a fully coupled atmospheric-wave-surface current model that is driven by a fully coupled wind-wave data assimilation procedure. The goal will take many years of effort to achieve, especially for the highly specialized data assimilation components.

There are two main benefits of this project in the context of PERD. First, by developing the modelling and assimilation tools to make effective use of all sources of data concerning the air-sea interface and its changes in space and time, the environmental factors governing regulatory and design criteria can be re-evaluated. Hindcasts and extreme storm scenarios can be reanalyzed in light of the new data and techniques that become available as a result of this research. Second, the new techniques for combining data and models are expected to greatly improve the ability to effectively monitor the marine environment, including climatological studies, and short-term analysis and forecasting of marine storms. This brings advantages of improved safety through better and earlier warning of hazardous conditions, and economic advantages through more effective planning of offshore activities. This project supports EC by making improved wave analysis and forecasting systems available for use in operational wind and wave forecasting. Finally, it helps EC provide better services to its clients.

Outputs and Methodology

End products include upgraded wave models, including higher resolution, shallow water physics, coupled to atmospheric models. On the data assimilation side, outputs include algorithms for the interpretation of remotely sensed wind and wave data, and the optimal combining of such data with wave models. Success is measured partly by the acceptance of papers on the new models and analysis techniques for publication in peer-refereed journals, and partly by the transfer of the technology to operational use, and to other interested users of wind-wave analysis and forecast systems. Success also will be measured by the impact of the new techniques on the establishment and/or revision of design criteria for marine structures.

This work is essentially all computer algorithm development and testing (i.e., evaluating the algorithms against observations obtained from many different sources). The project does not include field studies or actual measurements, although data from field studies is used whenever possible. Models are usually obtained from within the international scientific community and adapted or updated, then evaluated for application in Canadian waters. Data assimilation algorithms are obtained from within EC, and development of new or extended algorithms must be consistent with those of EC, in order to facilitate technology transfer into operations at a later date. Models for the interpretation of specific data types (e.g., satellite wind observations from ERS-2) are obtained from other operational weather centres that have developed them.

Funding

The average resources allocated for this project per fiscal year were $355k (1999–2000; 2000–2001). An average 67.6% of these resources came from PERD funds, the rest came from other sources (A-Base, industry). The average leverage quotient of total resources to PERD resources was 1.5.

Strategic Intent 1 · Strategic Direction 2 · Objective 1.2.3

Regulatory Requirements for the Safe and Efficient Transportation of Oil and Gas by Tankers, and for Other Occupational and Public Safety Standards. (Multiplayer)

POL 1.2.3

The Marine Transport and Safety (MTS) Program is a grouping of coordinated research initiatives from various federal departments that involve regulatory requirements relating to the safe and efficient transport of oil and gas by tankers and for other occupational and public safety needs. The components of the program focus on Navigation, Ship Design, and Offshore Safety. The research for POL 1.2.3 is accomplished by the same agencies and departments as described in POL 1.2.1.

The following activities are covered under POL 1.2.3:

- Navigation (EC participates in this activity)
- Ship Design
- Offshore Safety

POL 1.2.3 is scheduled to span 2000–2001 to 2003–2004. Average total funding per year for this POL is $1.92M. The proposed average PERD funding per year was $787k for fiscal years 1999–2001. PERD funds were divided amongst the departments involved in this POL (see Table 5). For this POL, the average leverage quotient of total resources to PERD resources was 2.4.

Table 5
Percentage of PERD Funds for POL 1.2.3 Allocated to Each of the Departments

Department	Percentage of Funds (%)	
	1999–2000*	2000–2001
TC	40.4	40.4
NRCan	32.8	32.8
NRC	16.6	16.6
DFO	5.1	5.1
EC	5.1	5.1

*PERD activities were organized differently in 1999–2000.

Profiles by Strategic Intent

Oil and Gas Sector

Regulatory Requirements for Occupational and Public Safety

Prediction of Small Glacial Mass Distributions

Environment Canada Projects for POL 1.2.3

Prediction of Small Glacial Mass Distributions

Project Manager: Tom Carrières

Overview
This project was a spin-off of the *Operational Ice Modelling* project. The main thrust is to provide support to shuttle tankers operating between the Grand Banks oil fields and their market. The most serious hazard for these vessels are the small iceberg pieces (growlers and bergy bits) which are very difficult to detect.

Objectives
The goal is to start issuing guidance products by the completion of the project. The project benefits the CIS and EC by expanding EC's iceberg knowledge and by adding capability to services. The validation effort for this model also should provide information for CIS coupled ice-ocean modelling efforts.

Outputs and Methodology
The approach is to build a model that can predict the calving, drift, and deterioration of these small iceberg pieces. To date very little research has been done in this area; therefore, a significant part of the effort is to conduct field experiments to gather information for basic model parameterization and calibration.

Funding
The average resources allocated for this project per fiscal year were $145k for 2000–2001 (funding for 1999–2000 was not available). An average 55.2% of these resources came from PERD funds, the rest came from other sources (A-Base, industry). The average leverage quotient of total resources to PERD resources for this project was 1.8.

Strategic Intent 1 · Strategic Direction 3

Strategic Direction 3 is to provide S&T to address cross-cutting environmental and safety issues to support the production of Canada's onshore and offshore oil and gas resources.

Strategic Intent 1 · Strategic Direction 3 · Objective 1.3.1

The Regulation and Reduction of GHG and Other Atmospheric Emissions, Primarily from Flaring. (Single Player)

POL 1.3.1

The oil and gas industry in Alberta achieves a conservation rate of roughly 92% of the solution gas produced. The rest is treated as a waste product and disposed of by combustion in a flare. There is pressure on industry and government to reduce or eliminate flaring due to public concern about potential health effects of solution gas volumes flared by industry. The practice of flaring is also an environmental concern as it wastes a valuable non-renewable energy resource and is a significant contributor to GHG emissions. The efficiency of flaring is currently unregulated due to the lack of science available to provide a sound basis for meaningful regulation of flaring. In 1998, industry, government, and other organizations in the Clean Air Strategic Alliance agreed to address the issues relating to routine solution gas flaring in Alberta. As a result of those deliberations, this project is now the cornerstone for flaring research in Canada. The proposed Flaring Research Initiative (FRI) is a coordinated research initiative lead by Environment Canada to reduce or eliminate the harmful effects of flaring solution gas. The FRI POL is comprised of a number of projects, undertaken with the support of industry, and federal and provincial government agencies. The work responds to the PERD focus on sustainable development opportunities and government responsibilities by developing new environmental regulations for flaring that contribute to the reduction of environmental impacts and GHG emissions. The research has progressed to the point that the initial results are being presented in international forums. The Alberta Energy and Utilities Board is generally regarded as a model for regulation in the oil and gas industry.

POL 1.3.1 is scheduled to span 2000–2001 to 2003–2004. Average total funding per year for this POL is $1.0084M. Total proposed funding allocated to EC to carry out these activities is $566.7k per year from PERD, representing 100% of PERD funding since EC is a single player in this POL. For this POL, the average leverage quotient of total resources to PERD resources was 1.8.

Profiles by Strategic Intent

Oil and Gas Sector

Regulation and Reduction of Atmospheric Emissions

Standards for Testing and Certification

Environment Canada Project for POL 1.3.1

Standards for Testing and Certification of Environmentally Efficient Flaring

Project Manager: Bill Reynen

Overview

This FRI research continues from the previous **Standards for Testing and Certification of Environmentally Efficient Flaring** project (1998). The project originated from the Combustion and Environment Group at the University of Alberta in partnership with the NSERC, CAPP, EC, the Alberta Energy and Utilities Board, Mactronic Flare Inc., and Amoco Canada. Environment Canada leads this research, contributing over half of the total funding requirements. Other collaborators include CANMET (NRCan), Alberta Department of Energy, Alberta Energy and Utilities Board, Alberta Environmental Protection, Alberta Science and Research Authority and Exploration, Petro-Canada, Talisman, Anderson, BP, Synergas, Crestar, Ontario Hydro, and Gulf Canada.

Objectives

This research aims to quantify flare efficiency as a function of various operating conditions; to investigate design and operational factors to improve flare efficiency; and, to develop a code of practice for testing and certification of flares.

The following overview describes on-going projects and their objectives:

- *Flare Performance*—to determine flare performance and factors influencing combustion efficiency; examine alternate uses for waste gas streams to reduce flare volumes; and develop technology to improve flare performance.
- *Flare Speciation*—to identify the potential products of incomplete combustion.
- *Liquid Removal*—to determine the influence of liquid carryover on flare performance and the means of reducing or eliminating such influences.
- *Fate and Transport*—to perform field studies to determine the fate and distribution of any products identified in the Speciation research.

Flaring research contributes to EC's mandate for clean air for Canadians and addresses the following government priorities:

- *Environmental benefits*—determination of flare efficiencies will allow more accurate estimates of the impact flaring is having on the environment leading to more efficient flare design and reduced emissions. The work will provide a means for making accurate environmental impact calculations using dispersion and deposition models for pollutants such as NO_x, SO_x, and trace compounds that survive the combustion process.
- *Scientific knowledge*—estimates of flare efficiency vary widely and their impact on the environment is disputed. This research will examine the factors affecting flare efficiency leading to improved flare design and efficiency.
- *Job creation*—the development of standards, test procedures, and/or design improvements could create a new service industry for the estimated 5000 flare stacks operating in Alberta.

Outputs and Methodology

- Development of improved production practices manuals through provision of at least one industry manual for improved field operations annually.
- Characterization and quantification of the effects flare emissions have on combustion efficiency.
- Identification of factors influencing flare combustion by compiling a list of factors (at least four).
- Develop technologies and practices to remove entrained liquids and improve flare performance.
- Develop alternative technologies to reduce flare volumes and improve solution gas utilization.
- Determine the fate and transport of emissions from solution gas flares by developing a comprehensive list of pollutants in flare emissions identified from at least three sites.

The approach used in this project is based on overcoming difficulties in measuring combustion efficiency and total pollutant product formation from flares in the atmosphere. Thus, flare efficiency is measured using scaled-down flare stacks mounted in a closed loop wind tunnel. The outputs from ongoing FRI projects will be achieved through various methods including conducting field pilot tests, lab and field testing at test facilities, developing models for forecasting (e.g., predict production rates of toxic compounds), consultation with industry association and regulatory bodies, and peer review of scientific reports. The measurements made during experiments include measuring overall efficiency, NO_x emissions, flow visualization of visible flames and combustion, and liquid fuel droplet aerosols.

Funding

The average resources allocated for this project per fiscal year were $1.0084M (1999–2000; 2000– 2001). An average of 56.2% of these resources came from PERD funds, the rest came from other sources (A-Base, industry, others). The average leverage quotient of total resources to PERD resources for this project was 1.8.

Strategic Intent 1 · Strategic Direction 3 · Objective 1.3.3

The Remediation of Groundwater and Soil Issues. (Multiplayer)

POL 1.3.3
This POL addresses groundwater and soil remediation issues in the context of activities related to the oil and gas industry. Pollutants, such as hydrocarbons, can infiltrate and contaminate soils and groundwater causing environmental problems that affect ecosystem health. This research focuses on developing and improving technologies to remediate contaminated sites, and also on improving containment in the event of accidental contamination. Once the remediation technologies are accepted, regulated, and implemented, the environmental impact of oil and gas production will diminish.

The projects are grouped into three activities in which EC participates:

- modelling and monitoring the fate and behaviour of hydrocarbons in soils and groundwater;
- developing or improving remediation technologies for hydrocarbon contamination that would benefit the oil and gas industry by being more effective, efficient, economical, and/or environmentally conscious; and,
- developing guidelines or standards for hydrocarbon concentrations in soil and groundwater.

This POL focuses on six areas:

1. *Environmentally Acceptable Endpoints*—developing standardized terrestrial toxicity tests and recommending environmentally acceptable endpoint values for cleanup of petroleum hydrocarbon contaminated sites.
2. *Natural Attenuation*—using natural attenuation as a contaminated site management tool.
3. *Phytoremediation*—using plants and plant-based products for the remediation of sites impacted by mixed contaminants.
4. *Mixed Contamination*—developing technologies to remediate contaminated sites containing mixtures of hydrocarbons and inorganic compounds (e.g., heavy metals).
5. *Oxygen limited environments*—improving/validating modelling data to characterize and evaluate hydrocarbon degradation in anaerobic conditions.
6. *Solar Detoxification*—developing solar-based oxidation technologies for destroying hydrocarbons in groundwater (to start 2001).

POL 1.3.3 is scheduled to span 2000–2001 to 2003–2004. Average total funding per year for this POL is $2.57M. The proposed average PERD funding per year was $912k for fiscal years 2000–2004. PERD funds were divided amongst the departments involved in this POL (see Table 6). For this POL, the average leverage quotient of total resources to PERD resources was 2.8.

Table 6
Percentage of PERD Funds for POL 1.3.3 Allocated to Each of the Departments

Department	Percentage of Funds (%)			
	2000–2001	2001–2002	2002–2003	2003–2004
EC	84.0	80.7	78.0	-
NRCan	16.0	19.3	17.0	-
POL Evaluation	0	0	5	

Environment Canada Projects for POL 1.3.3

Standardization and Validation of Terrestrial Toxicity Test Procedures for Assessing Biological Effects in Hydrocarbon Contaminated Soils

Project Manager: Richard Scroggins

Overview
This work was initiated originally as part of an industry-funded program sponsored by the Canadian Association of Petroleum Producers (CAPP) to develop a site-specific Ecological Risk Assessment approach to assess the hazard of petroleum products or wastes in soils. In 1993, CAPP sponsored a multi-year research program to develop and demonstrate an ecologically based approach for establishing site-specific contamination cleanup objectives using standardized aquatic and soil toxicity tests. However, toxicology experts were only able to recommend two soil toxicity tests: (1) earthworm survival using *Eisenia andrei* and (2) seed germination using two species. Other soil toxicity tests identified that would measure more ecological relevant endpoints and use species more relevant to Canadian soil systems were not recommended due to the lack of standardized testing procedures. The overall 1993 CAPP research project succeeded in demonstrating a process for deriving site-specific ecologically based contaminant cleanup objectives using their battery of toxicity tests; however, provincial regulatory authorities have been reluctant to accept this approach. Thus, there is a need for further research into environmentally acceptable endpoints.

In the past four years, industry has been funding a project to develop more environmentally acceptable endpoints for assessing petroleum hydrocarbon in soil (part of *Pollution Prevention and Control Technologies in the Oil and Gas Industry*). As a major component of this project, soil toxicity data are being generated using the research test procedures that have been developed through this PERD project.

Objectives
This research aims to:

- standardize new terrestrial soil toxicity test procedures using species relevant to Canadian soil systems; and
- field validate the toxicity tests using contaminated soils from facilities that produce natural gas and other alternative hydrocarbon-based fuels.

The research, including CAPP's site-specific, ecologically based objectives approach, is very relevant and beneficial to EC programs such as CEPA's Environmental Quality Guidelines program (i.e., need better methods for the derivation of soil quality criteria) and CEPA's Code of Good Environmental Practice for Industrial Site Decommissioning. With the development of a scientifically sound ecological risk assessment process for setting remediation targets, industry is more likely to undertake voluntary cleanup actions before facility closure and site decommissioning. Less resources will be spent on cleanup of the historical contamination problems, making more resources available for exploration, production, and processing of environmental acceptable alternative fuels. Finally, the research contributes to federal involvement in Canadian Council of Ministers of the Environment (CCME) initiatives such as the "Hydrocarbon in Soil" Canada-Wide Standard and the new National Contaminated Sites Program.

Profiles by Strategic Intent

Oil and Gas Sector

Remediation of Groundwater and Soil Issues

Validation of Terrestrial Toxicity Test Procedures

Outputs and Methodology
The principal outputs are the publication of three standardized toxicity test method documents as part of EC's biological test method series, including tests for:

- seedling emergence, early seedling growth, and plant vigour using terrestrial plants;
- survival, avoidance, and reproduction responses using earthworms; and
- acute toxicity and reproductive responses using springtails.

The immediate application would be to use the three new soil toxicity test methods to enhance the test battery used in the CAPP Ecological Risk Assessment approach and in generating data required for the Canada-Wide Standard "Hydrocarbon in Soil". Standardized soil toxicity tests would likely be cited as recommended monitoring tools in various provincial and federal soil contamination assessment and remediation programs and legislation. There will be a number of supporting research reports available outlining the work that has been conducted during the project for each of the three test methods.

Funding
The average resources allocated for this project per fiscal year were $100k (1999–2000; 2000–2001. An average 60% of these resources came from PERD funds, the rest came from other sources (A-Base, industry, other). The average leverage quotient of total resources to PERD resources for this project was 1.7.

Pollution Prevention and Control Technologies in the Oil and Gas Industry

Project Manager: Bill Reynen

Overview
This project is a continuation of the previous PERD project *Pollution Prevention and Control Technologies in the Oil and Gas Industry (1997)*. The research studies the fate, transport, and toxicity of contaminants and then applies innovative technologies to promote more sustainable practices in the oil and gas sector.

This work is part of a joint initiative with industry and the province of Alberta. It was originally led by the Environmental Research Advisory Council (ERAC) which was part of the CAPP. The CAPP was formed to initiate research and technology development on environmental issues relating to the production of crude oil and natural gas in Western Canada. The work is now being coordinated under the Petroleum Technology Alliance Canada (PTAC) through a Soil and Groundwater Technical Steering Committee, replacing the role of ERAC. This committee consists of the Federal and Provincial governments and industry, including CAPP. To date, the work has been successful because it has been conducted jointly with CAPP, member companies, public utilities, and other government agencies.

Objectives
A list of projects and their objectives follows:

- *Monitored natural attenuation*—to evaluate monitored natural attenuation as a cost-effective method of remediating contaminated sites to acceptable environmental levels at upstream oil and gas sites in Alberta.

- *Constructed wetlands*—to evaluate the effectiveness of constructed wetlands as a remediation tool.

- *Environmentally Acceptable Endpoints (EAE)*—to determine toxicity limits of residual hydrocarbons in soil. The research specifically contributes to federal involvement in Canadian Council of Ministers of the Environment (CCME) initiatives such as the "Hydrocarbon in Soil" Canada-Wide Standard.

- *Consolidated Tailings*—to assess the impact of sulphate addition on the microbial and chemical properties of the fine tailings from the consolidated tailings process in oil sands operations; to determine whether biogenic gases are formed, and predict if these gases affect the levels of fugitive emissions from terrestrial and aquatic environments.

The oil and gas industry is a major contributor of air, water, and land contaminants in addition to greenhouse gases. This project will use its relationship with industry to help foster partnerships for future work. This research benefits EC by addressing air, water, and land issues, and other government priorities including:

- *Environmental Protection*—This project examines environmental issues and corresponding technologies for preventing and minimizing the release of contaminants from the oil and gas industry to the environment. Application of such technologies will prevent or remove toxic substances from the environment and minimize emissions and waste.

- *Health and Safety Promotion*—The technologies studied will provide options for preventing and controlling industry contaminants; thereby, removing threats to health and safety.

Regulation—Regulators can use the findings of this work to assess situations under which application of the finding and associated technologies would be appropriate. For example, in contaminant fate and transport work, the findings can be used to determine if regulations or cleanup guidelines for contaminated sites should address the classes of compounds examined in this project.

Outputs and Methodology
The outputs for this research include:

Output 1—Development of improved/validated input data for modelling the fate and behaviour of hydrocarbons in anaerobic environments based on agreement between predictive model outputs and field validation data. The goal is to develop one standard protocol (2002) and one model (2004).

Output 2—Development of remediation technologies for hydrocarbon contamination in groundwater or soil. New technologies will be assessed based on cost, effectiveness, and potential to be environmentally innocuous. The goal is to assess four new technologies by 2004.

Output 3—Use of supporting data to advance the development of guidelines and/or standardized tests for hydrocarbons in groundwater and soils. The goal is to develop one Canada-Wide Standard setting process for hydrocarbons in soils and one site-specific cleanup standard developed for hydrocarbons in soils.

Funding
The average resources allocated for this project per fiscal year were $820k (1999–2000; 2000–2001). An average 23.8% of these resources came from PERD funds, the rest of the came from other sources (A-Base, industry, other). The average leverage quotient of total resources to PERD resources for this project was 4.2.

Wetlands—Containment, Transformation, and Remediation of Toxic Organics from Natural Gas Condensates and Process Chemicals

Project Manager: John Headley

Overview

This work stems from and will build on the results from earlier PERD research on groundwater (1997). Initial investigations involved instrumentation and characterization of the affected wetlands. The results of these investigations indicated that natural boreal wetlands are capable of removing and fixing hydrocarbon contaminants over time. If these findings prove to be true in general, the implications are significant. Hydrocarbon spills in wetlands might best be dealt with through monitoring and stimulation of natural mechanisms causing degradation, rather than by excavation or trenching. These more traditional, aggressive methods may often damage or even destroy the ecosystem they are trying to protect.

There is substantial evidence that wetland systems have a natural ability to assimilate and degrade anthropogenic contaminants. Although wetlands have been used for treatment of municipal waste and mine drainage, the use of wetlands as a viable treatment option for treatment of waste at gas plants has not received widespread acceptance. This research aims to increase the understanding of the attenuation mechanisms in natural wetlands. There is a need to perform systematic investigations of natural wetlands to better understand how they can be used for cost-effective treatment of waste at gas plants. Additional information on the impact of accidental spills on wetlands ecology is required. Knowledge gained from the proposed study of natural wetlands attenuation processes is anticipated to be directly applicable to the design of constructed wetlands.

Objectives

This research focuses on the use of natural wetlands for the treatment of toxic substances in gas condensates and associated process chemicals at participating gas plants in Alberta, using the Toxicity Identification Evaluation (TIE) approach developed for gas plant sludges and contaminated groundwater. The project is designed to extend the analytical/toxicity methods for gas plant sludges and contaminated groundwater to determine the effectiveness of wetlands in attenuating toxic contaminants and their transformation products in gas condensates. The research will also evaluate the effects of hydrocarbons on wetland ecosystems and develop a model to describe the behaviour of natural gas condensate and process chemicals in wetlands for general management and treatment of waste at gas plants.

The proposed research will benefit EC by supporting EC's commitment to the development of codes of practice and guidelines for the environmental protection of wetlands and by advancing the scientific knowledge on sustaining renewable energy resources. This research area is high priority as it supports initiatives to develop and implement treatment options for contaminated groundwater discharging into wetland areas at gas plants.

Outputs and Methodology

- Developing a standard protocol (March 2002) based on a TIE approach for the quantification of the degree of attenuation of principal toxic substances which are transformed or remediated in natural wetlands at participating gas plants;

- Evaluating attenuation processes (March 2003) to assess the fate and transport of contaminants in natural wetlands at participating gas plants; and,

Profiles by Strategic Intent

Oil and Gas Sector

Remediation of Groundwater and Soil Issues

Wetlands—Containment

- Generating a model (March 2004) describing the transformation and remediation of toxic contaminants based on measurements of attenuation of principal toxic components in natural wetlands at participating gas plants.

The project will apply a TIE approach to measure the effectiveness of attenuation mechanisms for removal of toxic substances at hydrocarbon-affected wetland sites in Alberta between April 1998 and March 2004. The results will be based on field samples and laboratory testing, in which the winter portion of the study will enable an assessment of attenuation of toxic substances in cold temperatures. The wetland study areas include Gulf Strachan and two Amoco sites, covering a broad spectrum of toxic compounds, including condensate, sulfolane, amine nitrogenous compounds, and crude oil.

The National Water Research Institute (NWRI Saskatoon) leads this project with the help of key participants in the private sector (Komex International, Envirotest Labs, Hydroqual Labs), academia (University of Alberta, University of Saskatchewan and Utah State University), and other government organizations. As part of technology transfer, the results will be published and presented in the scientific literature, workshops, and conferences (e.g., SETAC) as the work progresses each year. The lead scientists and hydrogeologists will also provide their expertise in an advisory and consulting role to industry and government as required. Upon completion, a final project report will be prepared by the key participants outlining the results of the work on the effectiveness of wetlands to contain and remediate toxic contaminants.

Funding
The average resources allocated for this project per fiscal year were $240.8k (1999–2000; 2000–2001. An average 30.1% of these resources came from PERD funds, the rest came from other sources (A-Base, industry/academia, other). The average leverage quotient of total resources to PERD resources for this project was 3.3.

Biological Barriers in Fractured Bedrock

Project Manager: Suzanne Lesage

Overview
This project stems from a Ph.D. project conducted at L' École Polytechnique de Montréal (Ross *et al.,* 1998; Ross *et al.,* 2001; Ross *et al.,* 2001) and a M.Sc. thesis conducted at the University of Waterloo (Lapcevic, 1997; Lapcevic *et al.,* 1999). This project includes several partners each receiving matching funds from other programs such as NSERC. The National Water Research Institute (NWRI) is funded by EC A-Base and the Great Lakes Water Quality Program; L' École Polytechnique de Montréal is funded by NSERC and multiple industrial partners, and Queen's University is funded by NSERC.

Objectives
The project is aimed at reducing the permeability and preventing migration of contaminants in a fractured media by injecting a carbon source to stimulate the groundwater microbial population. In the context of PERD, this multidisciplinary project will provide knowledge to advance the development and/or the refinement of remediation technologies. The biostimulation approach (i.e., the injection of nutrients for the development of a biobarrier) fits into the use of renewable energy for remediation of contaminated soils and groundwater. The biobarrier represents an innovative method to improve bioremediation and off-site migration.

This project will benefit EC through the development of an innovative "green" technology. In addition, the biological barrier concept could provide a remediation tool for orphaned, polluted, fractured rock sites. Data obtained from the microbiological and ecotoxicological analyses will support Environment Canada's environmental regulations, such as the *New Substances Notification Regulations* under CEPA.

Outputs and Methodology
Output 1: Knowledge on the possibility of enhancing natural attenuation using natural adjuvants. This knowledge will be obtained using two laboratory apparatus as described by Hoag (1995) and Ross (1999). Work will be conducted in parallel at the NWRI and L' École Polytechnique de Montréal. Under constant groundwater flow and carbon source injection, the bio-clogging of single fracture models will be monitored by measuring biofilm development and analyzing effluent components. The possibility of using the biobarrier technique as a containment barrier (significant reduction of permeability) and/or reactive wall (significant reduction of contaminant concentration) will be determined. Laboratory experiments will be divided in several experimental designs and the duration of the work will be three years. The determination of design parameters for the biobarrier is targeted for March 2003.

Output 2: Evaluation of the bacterial community and the ecotoxicology of the method using biomolecular techniques (Note: This partially addresses the environmental endpoint priority). The assessment of the biosafety of biostimulating an indigenous microflora will be carried out at both laboratory and field sites. The glass fracture table will be used to determine the most relevant monitoring tools for the field (Mississauga, ON). It is planned to test a battery of biomolecular analyses and bioassays (results after years two and four), and use selected techniques to monitor microbial diversity changes and ecotoxicological responses at the Mississauga site. This part of the project will take three years and will be conducted by NWRI/EC partners.

Output 3: Field trial of an innovative "green" technology of containment (Validation of the approach of biobarrier by March 2003).
The field trial will be conducted on a horizontal fracture in limestone shale (Petro Canada Lubricants, Mississauga, ON) to determine: (1) the technical feasibility of the biobarrier concept; (2) the design parameters for a full-size field scale; and (3) how "green" is the concept. The duration of the work will be three years with the first year being used for field setup (e.g., drilling of new boreholes, pumping tests, etc.). The experiment will consist of supplying the carbon source and measuring the extent of bio-clogging. One major concern will be to evaluate the longevity of the biobarrier because longevity is crucial for the acceptability of this technology as "green". Also, there is still uncertainty about the fate of contaminants adsorbed on the biofilm and the microbial products excreted through bacterial growth and lysis.

Output 4: Experimental results supported by modelling (March 2003).
Mathematical models will be developed specifically for bacterial transport and biofilm development in fractured media. Fractured rocks remain an unexplored media for modelling bacterial development. Models will be generated using laboratory experiments (conducted at NWRI/EC) for the comparison of several test conditions (e.g., with and without contamination). Also, the field trial will be used to validate the approach of the biobarrier and to improve the models.

Funding
The resources allocated for this project were $360k for 2000–2001 (funds were not available for 1999–2000). An average 20.8% of these resources came from PERD funds, the rest came from other sources (A-Base, industry, other). The average leverage quotient of total resources to PERD resources for this project was 4.8.

Assessment of Phytoremediation as an* In-situ *Technique for Cleaning Oil-contaminated Sites

Project Manager: Terry McIntyre

Overview
This project does not stem from a previous PERD project. In 1998, the Environmental Biotechnology Applications Division of Environment Canada (EBAD), established a phytoremediation program to assess the potential use of plants to remediate and restore contaminated sites and their associated regulatory oversight. In addition, EBAD is developing field demonstration protocols and fully searchable data bases containing potential phytoremediation candidates. EBAD is interested in exploring phytoremediation as an alternative to the conventional physicochemical technologies to remediate sites contaminated with metals and hydrocarbons. Recently, EBAD has become a member of the United States Environmental Protection Agency (USEPA) Remediation Technology Development Forum (RTDF). This will allow EBAD to have access to over ten field demonstration sites across the United States. The PERD component of the program encompasses phytoremediation R&D activities and is being delivered in partnership with the University of Saskatchewan. Additionally, work is being conducted with a phytoremediation consulting company on a research project in the greenhouse/growth chamber.

Objectives
These include evaluating the effectiveness of phytoremediation as a means of reducing the hydrocarbon concentrations in soils and groundwater contaminated with weathered crude oils/refined oil products. Phytoremediation constitutes a group of innovative environmental solutions that is consistent with environmental priorities as highlighted in the speech from the throne and the Canadian Biotechnology Strategy. With an estimated 70 000 active sites having hydrocarbon contamination in the province of Alberta alone (Canada's oil and gas industry centre) and the associated prohibitively expensive cleanup costs, investigation for cost-effective solutions is a priority. Plant-based remediation technology may provide an important contribution to bring these sites to an acceptable level of environmental health.

EC's involvement in the phytoremediation R&D has allowed the establishment of a good network of phytoremediation practitioners in Canada, the United States, and abroad. This network has evolved into a solid collaborative partnership with industry, municipal and provincial governments, and other federal departments. It has also allowed EC to work in cooperation with the USEPA to develop complementary research. As a participant of the RTDF group, EC has full access to data generated by the field demonstration projects. Besides having access to these data, EC also exchanges information monthly with the scientists/managers of these sites. This allows EC to fine-tune research strategies and provide information on the research findings related to phytoremediation of hydrocarbons.

Outputs and Methodology
The main output stemming from this initiative includes the improved understanding of the potential and limitations of phytoremediation as a cleanup technology for Canadian ecozones. Associated performance indicators include reports and publications summarizing the results of the research conducted during the course of the project.

The activities planned under this initiative are essentially of a research and development nature, such as field demonstration projects (four sites in Saskatchewan) and greenhouse/growth chamber studies. Field demonstration projects are conducted on contaminated sites and have been selected based on the representation of the Canadian contaminated site problems. Greenhouse/growth chamber studies are done with soil collected from contaminated sites, as much as possible. Where not feasible, spiking follows as closely as possible to contamination as it occurs in the contaminated sites found in Canada.

Funding
The average resources allocated for this project per fiscal year were $144.5k (1999–2000; 2000–2001). An average 39.4% of these resources came from PERD funds, the rest came from other sources (A-Base, industry, other). The average leverage quotient of total resources to PERD resources for this project was 2.5.

Profiles by Strategic Intent

Oil and Gas Sector

Remediation of Groundwater and Soil Issues

Simultaneous Recovery of Inorganic Contaminants and Hydrocarbons

Simultaneous Recovery of Inorganic Contaminants and Hydrocarbons from Soils Using Chelation/Solvent Extractions

Project Manager: Brian Mansfield (new contact: Carl Brown)

Overview

This project follows bench-scale and pilot plant work carried out by the Emergencies Engineering Division (EED) of EC and McGill University in 1998. In the earlier work it was discovered that the use of a chelation/solvent combination would simultaneously remove heavy metal and organic contamination from soils. Current research is carried out through the Environmental Technologies Program of SIAC Canada (formerly EED). The Canadian Petroleum Products Institute (CPPI) was contacted to help provide a site for the research and development.

Objectives

This project explores the engineering research and development of an advanced Chelation/Solvent Extraction Process (CHELASOL) for the simultaneous removal of organic and inorganic contaminants from soil at sites such as former oil refineries and processing plants. It benefits EC as it addresses areas such as pollution prevention and environmental enhancement (e.g., extraction of pollutants from contaminated sites). The mixed pollutants at former oil industry sites can migrate and affect local groundwater supplies, which, in many areas of Canada, are the sources of drinking water for local communities. In addition to providing a means to effectively clean up these contaminated sites, the cleaned sites can then be used for the development of new industries and associated job creation. This research contributes to EC's objectives of eliminating toxic substances from soil and water.

Outputs and Methodology

- *Output 1—Selection of appropriate chelant/solvent pairs.* This was achieved through an extensive literature search. Assistance was obtained from researchers at Queen's University who developed a computer program of solvent selection by inputting a wide range of chemical and physical property criteria. Three potential pairs were identified and simple laboratory tests were undertaken to choose one pair, which was then tested more rigorously.

- *Output 2—Optimization and determination of effectiveness of selected chelant/solvent pairs.* The selected chelant/solvent pairs were used in a series of tests where various operating parameters were evaluated and the resulting contaminant removal efficiencies observed. These tests were run with sediment from an actual contaminated site containing heavy metals, PAHs, and PCBs among other contaminants. Three tests were run concurrently, one to evaluate the extraction of organic compounds using solvent extraction alone, one to evaluate the extraction of heavy metals using acid washing alone, and one to evaluate the extraction of heavy metals and organic compounds using the complete CHELASOL process.

- *Output 3—Evaluation of appropriate chelant and solvent recovery methods.* Tests were performed to determine if the solvent and chelant used in the process could be recovered and recycled for further use in the system. Using vacuum distillation, the solvent recovery was nearly 100%. Various methods were tested for the recovery of the chelant.

- *Output 4—Preparation of a preliminary process flow diagram and equipment selection and sourcing.* Based on the results of the testing performed a seven-step process flow diagram was proposed.

- *Output 5—Presentation of information sessions to the petroleum industry.* Presentations took place on June 9th, 2000 at a PTAC R&D information forum in Calgary, Alberta.

Funding

The resources allocated for this project were $110k for fiscal year 1999–2000 (funds for 2000–2001 were not available). An average 68.2% of these resources came from PERD funds, the rest came from other sources (A-Base). The leverage quotient of total resources to PERD resources for this project was 1.5.

Assessment of Natural and Anthropogenic Impacts of Oil Sands Contaminants within the Northern River Basin

Project Manager: Kevin Cash

Overview

The impetus for this work stems from a large ecosystem initiative (1998), the Northern River Basins Study (NRBS). The Northern Rivers Ecosystem Initiative (NREI) is a substantive followup study to the NRBS. The ongoing assessment of the natural and anthropogenic effects of oil sands contaminants within the Northern River Basins is related to and complements activities within the NREI. The groundwater and soil remediation POL incorporated the last two years of this ongoing assessment into POL 1.3.3 based on a decision by the members of the PERD Groundwater and Soil Remediation Steering Committee.

Outcomes of this research project will address recommendations from the NRBS Board Report to the Ministers of the Environment for Canada, Alberta, and the Northwest Territories. It was recognized that both oil sands development and natural exposure to oil sands deposits may result in concentrations of hydrocarbons and other substances that cause stress to fish and other biota. Within the ministerial response to the NRBS Board recommendations, PERD was identified as being an important partner in addressing the specific research recommendations from the NRBS; thus, this project was incorporated into the new POL process.

Objectives

This project assesses and predicts potential effects of hydrocarbon activities occurring in the Alberta oil sands area and distinguishes these effects from those produced by naturally occurring hydrocarbon deposits and releases. The scope of the research includes determining the environmental effects of natural hydrocarbon releases to the aquatic environment and distinguishing these effects from those produced by refinery processes and related effluents, as well as integrating these effects into an environmental monitoring and assessment framework. This project also directly addresses the PERD hydrocarbon strategic direction by providing insight into the effects of hydrocarbon activities within the oil sands and heavy oil industries through the development of environmental models and indicators.

Primary objectives of this project are to:

- address the NRBS Board recommendations to the Ministers regarding oil sands contaminant, fate, distribution, and effects in the northern basins area,
- provide an improved understanding of the nature and extent of natural hydrocarbon releases to the environment,
- distinguish between effects related to natural versus anthropogenic releases of oil sands contaminants to the environment,
- develop and field validate ecological tests that provide early warning of the effects on biota, and
- evaluate these and other tests for inclusion in an environmental effects monitoring program for the oil sands industry.

This research benefits EC because it is directly relevant to EC's Nature Business Line and one of its large Ecosystem Initiatives (i.e., NREI). Also, the research addresses government priorities including furthering the advancement of scientific knowledge and overall environmental benefits.

Outputs and methodology
The outputs of this work will include primary publications and a synthesis report. The information from the various sub-projects will be collected and rolled up later this year (2001).

The sub-projects include:

1. *Chemistry and ecotoxicology of organic compounds in bitumen froth relating to long-range transfer in oil sands operations*. I*n vitro* studies were carried out on model polycyclic organic compounds (PAC) using laboratory tests to determine the affinities of rat liver Ah receptor for 10 PACs.

2. *Fish health effects from oil sands wastewater discharges and naturally ocurring oil sands compounds in the Athabasca River system*. Biological testing based on sampling small fish species (e.g., slimy sculpin and trout perch) was used to support the development of a future environmental effects monitoring program. This study also focuses on teasing out the contributions of anthropogenic versus natural oil sands contamination.

3. *Long-range transport of hydrocarbons to the northern deltas and lakes: pathways and fate*. This study aims to delineate the spatial pattern and deposition history of PAH contaminants and assess the role of oil sands development in determining the patterns described. The research involved sampling sediments at various sites and conducting sediment grain size analyses.

4. *Identification and characterization of natural hydrocarbon release from oil sands deposits in the northern river basins area*. The research objectives are to characterize the spatial distribution of natural hydrocarbon seeps in rivers of the Athabasca and Peace river basins and to determine the movement of heavy oil contaminants in riverine sediments using field and laboratory components. Sampling was conducted on up to 12 sites to determine water quality, sediment, and biofilm.

5. *Ecological effects of natural versus anthropogenic releases of oil sands contaminants*. This sub-project was initiated in 1999 to provide a better understanding of effects of naturally occurring contaminants on aquatic food webs. Field studies (e.g., sediment sampling) were carried out and results from sediment toxicology experiments analyzed.

6. *The ecological viability of constructed wetlands at Suncor: population and health–related considerations in birds and amphibians*. Field studies were conducted to determine the utility of constructed and natural wetlands for remediating oil sands affected wastewaters and to develop a suite of sensitive assessment techniques for examining the health of birds.

Funding
The average resources allocated for this project per fiscal year were $1.0766M (1999–2000; 2000–2001). An average 45.3% of these resources came from PERD funds, the rest came from other sources (A-Base, other). The average leverage quotient of total resources to PERD resources for this project was 2.2.

Solar Detoxification

Project Manager: Carl Brown

Overview (for 2001)
A solar-based AOP technology called the SolAqua process was recently developed in Canada (Safarzadeh, Bolton, and Cater). In the SolAqua process (patent owned by Calgon), natural solar energy is used instead of artificial UV, thus presenting an opportunity for greatly reducing electricity requirements of AOP treatment plants. The SolAqua technology has been tried and found effective on a number of contaminants at the laboratory scale. However, additional R&D work is required to bring this technology to the commercialization stage.

Objectives
The current work studies the efficacy of the SolAqua process over a range of organic pollutants common to petroleum production and processing. Initial work will be conducted at the benchscale level focusing on process parameters and contaminant destruction efficiencies. With appropriate industry partnership in place, a pilot-scale system will be designed and built for field testing at a selected industry site.

This project is important to the Groundwater Remediation Program for the following reasons:

(1) Funding supports the continuing development of an innovative groundwater remediation technology based on solar energy.

(2) If proven successful, PERD funding would significantly contribute to the reduction of the environmental effects of oil and gas production.

This project supports PERD's principle of sustainable development. The technology under R&D provides a unique opportunity for environmental protection based on a secure (and renewable) energy source. If commercialized, this solar-based remediation technology will reduce the burden on Canada's electricity infrastructure and at the same time demonstrate an innovative approach in alternative energy source application.

Profiles by Strategic Intent

Oil and Gas Sector

Remediation of Groundwater and Soil Issues

Solar Detoxification

Strategic Intent 2—Transportation Sector

Strategic Intent 2 is to foster cleaner sustainable transportation fuels and systems in order to improve the environment, reduce emissions, including GHGs, and to increase economic activity through development of domestic and export markets.

Strategic Intent 2 · Strategic Direction 1

Strategic Direction 1 is to provide S&T to reduce emissions from transportation sources to improve air quality and health and reduce GHG production.

Strategic Intent 2 · Strategic Direction 1 · Objective 2.1.1

Support for the Development of Technological and Other Measures to Control and Reduce Emissions of Particulate Matter. (Multiplayer)

POL 2.1.1

The Particles POL (2.1.1) is a coordinated set of research activities that focuses on improving our understanding of the formation, fate, and impact of particulate matter (PM) formed by transportation-related sources. It is a joint undertaking by five federal departments and agencies including Environment Canada, Health Canada, National Defence, Natural Resources Canada, and the National Research Council. The POL integrates seven existing research projects; each of the projects contributes to the overall objective of this research program—to improve technology and science in order to:

- reduce emissions of primary particles and precursors; and,
- strengthen policies and regulations on transportation fuels, engines, emissions, and air quality.

Taken together, these objectives will lead to improved air quality and reduced adverse health effects. The work to be done within this objective has been grouped into three activities:

- *Emissions*—develop technology to measure and control the formation and emission of particles and their precursors by transportation-related combustion sources;
- *Ambient Air*—develop measurement and modelling techniques and systems for atmospheric particles and their precursors produced by transportation-related combustion sources; and
- *Health Effects*—examine acute and chronic cardiorespiratory effects on humans of particles produced by transportation-related combustion sources.

POL 2.1.1 is scheduled to span 2000–2001 to 2004–2005. Average total funding per year for this POL is $2.075M. The proposed average PERD funding per year was $731k, for fiscal years 2000–2005. PERD funds were divided amongst the departments involved in this POL (see Table 7). For this POL, the average leverage quotient of total resources to PERD resources was 2.8.

Table 7
Percentage of PERD Funds for POL 2.1.1 Allocated to Each of the Departments

Department	Percentage of Funds (%)				
	2000–2001	2001–2002	2002–2003	2003–2004	2004–2005
EC	54.7	51.4	44.6	43.1	43.1
NRC	28.0	28.0	34.2	36.3	34.9
HC	17.2	11.6	15.1	8.6	15.5
DND	0	8.9	6.2	6.6	6.6
NRCan	0	0	0	5.5	0

Environment Canada Projects for POL 2.1.1

Determination of the Concentration, Composition, and Sources of Airborne Carbonaceous Particles in Canada

Project Manager: Keith Puckett

Overview
This PERD project stems from the PERD project *Determination of the Concentration, Composition, and Sources of Airborne Carbonaceous Particles in Canada*, which was a three-year project spanning 1999–2001. The new POL has an expanded scope, including additional emissions measurement and control projects. The project is part of the Ambient Air activity of the overall program.

The transportation sector is a significant source of PM and precursor emissions. This project brings together experts from each aspect of the issue, from emissions to atmospheric measurement and modelling, to acute and chronic health effects. The tight integration of these processes under one POL provides scientific as well as financial leverage.

Objectives
The overall goal of the ambient particulate characterization project is to gain insight into the transportation, transformation, and fate of ambient fine particles and their precursors, particularly those produced by emissions from the transportation sector. The project will build on previous work on characterizing vehicle emissions and develop improved analytical and ambient sampling methods, coupling these with improved data analysis techniques to:

- improve the understanding of the influences of transportation sources on the concentrations of $PM_{2.5}$ and related gaseous constituents in, and downwind of, major Canadian cities; and,
- provide improved data for the development and evaluation of air quality models used to predict ambient particles concentrations.

The project benefits and supports EC's Clean Air Strategy as well as domestic and international emissions reduction agreements including the recent Canada-Wide Standard on PM and Ozone, and a possible PM Annex to the Canada–US Air Quality Agreement. The work also will help further the discussion on the designation of PM as toxic under the auspices of the Toxic Substances Management Policy of CEPA. The impact of this work will be a decrease in transportation-related particles in the atmosphere and an associated reduction in health effects on Canadians.

Outputs and Methodology
Sampling and Analytical Techniques for Characterizing Primary Particles and Gaseous Precursors in Ambient Air will be achieved through:

- Development of new air sampling and analytical chemistry techniques for particles, including: sampling methods to reduce PM sample collection artifacts; analytical methods to determine the chemical characteristics of particles; and, development of improved semi-continuous and integrating methods for measurement of organic and elemental carbon.
- Compilation and analysis of ambient measurement data sets in order to: (1) develop and test various hypotheses regarding the influence of transportation sources on $PM_{2.5}$ concentrations; and (2) support the development and evaluation of air quality models.

The project will participate in a major field campaign (Pacific 2001) in order to evaluate and refine the sampling, analytical and data analysis methods under development. Field data collected during this project will be applied to produce direct estimates of the role of transportation and used to determine the nature and source of carbonaceous fine particles, which will strengthen scientific support to policy and regulation development. Other targets are to provide the relative importance of current transportation sources to ambient particulate matter (anticipated by 2005); as well as papers and presentations on sampling and analysis techniques (2003 and 2005) for characterizing primary particles and gaseous precursors in ambient air.

Funding

The average resources allocated for this project were $2.366M for 2000–2001 (funds for fiscal year 1999-2000 were not available). An average 30.9% of these resources came from PERD funds, the rest came from other sources [A-Base, industry, other (TSRI)]. The average leverage quotient of total resources to PERD resources for this project was 3.2.

Profiles by Strategic Intent

Transportation Sector

Control and Reduction of Particulate Matter Emissions

Characterization of Particulate—Transportation Fuels

Characterization of Particulate—Transportation Fuels

Project Manager: Lisa Graham

Overview

This project follows a PERD project which focused on the development of methods to characterize and model particles emitted by transportation sources. The new POL spans fiscal years 2000–2001 to 2004–2005 and describes a broadened suite of particles research activities. This research includes measurement and control of particles emissions and examination of acute and chronic health effects. The project is one of the seven in the overall program and it is part of the Emissions activity.

Primary emissions of particulate matter from mobile sources arise from fuel combustion, "wear" emissions and trace components in the fuel. Recent changes in the composition of fuels and in engine technology have had an impact on vehicle emissions, which are no longer accurately reflected in Canadian vehicle emissions profiles. These inadequacies in vehicle emissions profiles make it difficult to assess proposed vehicle technology or fuel formulation changes. This was demonstrated in the recent assessment by the CCME Task Force on Cleaner Vehicles and Fuels of the effects and benefits of reducing sulphur in gasoline. The lack of representative emissions profiles results in uncertainties that hamper decisions and, in the long-term, will hinder Canada's progress toward a sustainable energy future.

One aspect of mobile source emissions is the emission of elemental carbon and particulate bound organic carbon. Although diesel emissions are regarded as the primary source of elemental carbon emissions from mobile sources, contribution from light-duty gasoline vehicles can be important in areas where the diesel fleet is small. Emission rates of elemental carbon from light-duty vehicles are not well understood and the semi-volatile organic material that attaches to the surface of elemental carbon particles has not been fully characterized. In addition to this, it is recognized that gaseous emissions from mobile sources also contribute to the ambient particulate matter levels through gas-particle conversion as these gaseous compounds undergo chemical transformation in the atmosphere to produce particulate matter.

Emissions characterization includes:

- physical characterization of size distributions and number concentrations of particles emitted from traditional, new technology, and alternative fueled vehicles;
- chemical characterization of particles and gaseous precursors;
- investigation of transportation tracers for analysis of ambient particles and to support model development;
- measurement of the effect of sulphur levels on ammonia emissions; and,
- investigation of the contribution of lubrication oils to particulate matter.

Objectives

The objective of the emissions characterization project is the development of methods to characterize and model particles emitted by transportation sources; the objective will contribute to improved air quality and reduced adverse health effects. The emissions characterization research also will contribute to improvement of air quality models by addressing knowledge gaps and providing data for model development and evaluation. Of particular interest are the characteristics (mass, size distribution, and chemical composition) of primary particle emissions, chemical speciation profiles for gaseous emissions, and a better understanding of the chemistry and physics of aerosol formation.

Environment Canada will benefit because research from both the Emissions and Ambient Air activities will improve the confidence of policy makers in their decisions and help strengthen policies and regulations, stemming, in part, from answering the following questions:

- How could particles produced by combustion in transportation sources be controlled and/or reduced?
- What percentage of the currently observed atmospheric particle loading is due to Canadian transportation sources?
- How would the total atmospheric particle loading over Canada change given different Canadian policies on transportation and/or transportation fuels?
- What are the public health impacts and associated economic burden of transportation-related particulate matter in Canada?

Outputs and Methodology
Sampling and analytical techniques for fine particles and their precursors in exhaust of representative vehicle classes will be achieved through:

- Application of emissions data to improve modelling of particle chemistry and physics. Includes expanded emissions data in Pacific 2001 model evaluation.
- Citation in science assessments (e.g., science assessment for Canada-Wide Standards for PM and Ozone).
- Publication in peer-reviewed journals (e.g., papers on sampling and analysis techniques for chemical and physical characterization of fine particulate matter and gaseous precursor emissions from representative vehicle classes).
- Presentations at scientific conferences (annually).

The emissions measurement activities make use of the suite of analytical tools developed by NRCan-CETC and EC-AAQD for the current PERD program. The work will be carried out at the Environmental Technology Centre (ETC) of EC. A number of smaller project segments are planned for the Emissions task including laboratory emissions measurements on selected vehicles under well-controlled conditions, and field studies to measure emissions of a much larger number of vehicles than possible with laboratory testing, under a limited set of conditions.

Measurement methods will be developed and validated and the results reported to the program team and the Department. The results of this work, in conjunction with other measurements made within the program will be used in the modelling portion of the program to build tools for policy option evaluation.

Funding
The average resources allocated for this project per fiscal year were $506.7k (1999–2000; 2000–2001). An average 49.8% of these resources came from PERD funds, the rest came from other sources [A-Base, industry, other (TSRI)]. The average leverage quotient of total resources to PERD resources for this project was 2.0.

Strategic Intent 2 · Strategic Direction 1 · Objective 2.1.2

The design and use of gaseous and liquid hydrocarbon fuels and associated technologies to achieve emissions reductions. (Multiplayer)

POL 2.1.2

The Advanced Fuels and Transportation Emissions Reduction (AFTER) POL 2.1.2 focuses on reducing emissions from the Canadian transportation sector using new advanced fuel and transportation technologies, including innovative emissions control systems developed in Canada. The primary impact from this research will be improved air quality through reduced emissions, including regulated emissions VOC, CO, NO_x' and PM as well as GHG emissions. The research supports the development of new standards and regulations designed for reduced emissions from Canadian transportation sources. In addition, the research aims to contribute to increased economic activity through possible new markets for innovative, new Canadian transportation technologies and increased hydrocarbon sales, including oil sands crudes. Research areas include new fuels and engine hardware technology, engine combustion technology, and exhaust aftertreatment systems.

The AFTER POL is divided into the following three areas:

- development of new innovative technologies for gaseous and alternative fuel engines,
- gasoline and spark-ignited engine technology programs, and
- advanced diesel fuels and compression ignition engine technology.

POL 2.1.2 is scheduled to span 2000–2001 to 2004–2005. Average total funding per year for this POL is $4.363M. The proposed average PERD funding per year was $1.786M for fiscal years 2000–2005. PERD funds were divided amongst the departments involved in this POL (see Table 8). For this POL, the average leverage quotient of total resources to PERD resources was 2.4.

Table 8
Percentage of PERD Funds for POL 2.1.2 Allocated to Each of the Departments

Department	Percentage of Funds (%)				
	2000–2001	2001–2002	2002–2003	2003–2004	2004–2005
NRCan	34.0	33.9	34.7	37.0	38.4
NRC	16.2	20.0	26.0	28.8	29.7
TC	24.2	22.3	15.6	11.8	12.6
HC	12.0	12.0	12.0	12.0	12.9
EC	12.1	10.4	10.4	2.8	3.6
Planning & Support	1.4	1.4	1.4	7.6	2.9

Profiles by Strategic Intent

Transportation Sector

Design of Fuels to Achieve Emission Reductions

Engine Cold Start Efficiency

Environment Canada Projects for POL 2.1.2

Engine Cold Start Efficiency

Project Manager: Fred Hendren

Overview
This new project contributes to the AFTER POL activity to develop gas- and spark-ignited engine technology. It fits under the concept of efficient energy use which is part of an NRCan program that has existed for a number of years.

Objectives
This work supports the objectives of PERD by conducting R&D on technologies and/or processes that have the potential to reduce energy consumption and use energy more efficiently. The end result will be a technology or process that will be transferred to industry for commercialization.

EC benefits from this work through the development of technologies/processes that will reduce the pollution burden from mobile sources. The result would be improved air quality in urban areas. In addition, the data that are being generated from this study will enhance the department's knowledge base on exhaust emissions from the Canadian fleet under cold operating conditions. The work also is directly related to environmental protection and enhancement, and climate change initiatives under the Kyoto agreement.

Outputs and Methodology
The output from this work will be technologies or a technology and processes that will result in reductions in energy consumption for automobiles, primarily, but also for trucks. If the end result is a technology, this will be transferred to industry for commercialization. If a process is developed, the government could use this process to inform the public on how to save energy. The measurement of success is the demonstration of methods (technology and process) that will reduce the amount of fossil fuels that are consumed during engine cold starting. The target is a 10% reduction.

The study is being undertaken by conducting vehicle cold start exhaust emissions and fuel consumption testing in an EC test laboratory. The testing involves an evaluation of various technologies and processes that have indicated the potential for energy consumption reductions through an extensive literature search. None of the work conducted to date has been presented or published.

Funding
The average resources allocated for this project per fiscal year were $107.5k (1999–2000; 2000–2001). An average 44.2% of these resources came from PERD funds, the rest came from other sources (A-Base). The average leverage quotient of total resources to PERD resources for this project was 2.3.

Environmental Impact of the Use of Alternative and/or New Reformulated Fuels and Development of Advanced Engine/Vehicle Technologies for Use in Light- and Heavy-duty Motor Vehicles

Project Manager: Russ Robinson

Overview
This project stems from past PERD projects involving the assessment of the environmental impacts of alternative fuels (1998). It is part of EC's Plan of Action for cleaner vehicles, engines, and fuels as part of the Federal Clean Air Strategy.

Objectives
The purpose of this project is to assess the emissions and performance of alternative fuels and advanced engine/vehicle technologies for light- and heavy-duty motor vehicles. The major benefit of using advanced transportation fuels is the reduction of emissions from both light and heavy-duty vehicles.

Outputs and Methodology
Expected outputs from this project are assessments of the environmental impacts from the development of transportation fuels, advanced technologies, and their supporting infrastructure. Outcomes from this work would be the potential adoption of standards and regulations and input to government policies and programs. Performance indicators include analysis of environmental risks and benefits of transportation fuels and advanced technologies.

The following tasks are underway to assess environmental benefits of alternative fuels.

- Emissions from current model vehicles operating on ethanol/gasoline blends is under study. Seven vehicles are being tested for regulated emissions, ethanol and a large number of VOCs. The fuels include blends with 10, 15 and 20% ethanol in order to understand how well the latest engine emissions controls can cope with increased ethanol content of the fuel.

- A review of in-service natural gas and propane vehicle emissions trends over the past eight years from BC AirCare's Inspection and Maintenance Program was prepared by Pacific Vehicle Testing Technologies Ltd. This review provides emissions results and pass and failure rates for alternative fuel vehicles tested under the program.

- Environment Canada provides support to the Windsor Workshop on Transportation Fuels. This workshop is well recognized for the exchange of technical information relating to developments in conventional transportation fuels as well as alternative fuels, advanced automotive technologies, vehicle emissions, and combustion processes.

Funding
The average resources allocated for this project per fiscal year were $146k (1999–2000; 2000–2001). An average 93.2% of these resources came from PERD funds, the rest came from other sources (A-Base). The average leverage quotient of total resources to PERD resources for this project was 1.1.

Profiles by Strategic Intent

Transportation Sector

Design of Fuels to Achieve Emission Reductions

Environmental Properties of Diesel Ethers

Environmental Properties of Diesel Ethers

Project Manager: Merv Fingas

Overview
This project is a new initiative carried out in partnership with NRCan and HC. It is part of the AFTER POL activity to research advanced diesel fuels and compression ignition engine technology.

Objectives
The objectives of this project include:

- screening potential diesel ethers for environmental concerns related to water and soil; and
- measuring environmental properties of diesel ethers, particularly water solubility.

This project is beneficial to EC as it gives EC the opportunity to participate in the project from the ground up and provides the opportunity to screen potential candidates before they are used in large-scale tests. This project addresses federal government priorities in the transportation area including the reduction of GHG emissions. It is also beneficial to EC because it addresses the federal government responsibility for transportation emission regulations through the new CEPA legislation; R&D in this area is necessary for the development of new regulations.

Outputs and Methodology
Outputs will include reports on products screened; therefore, the number of products screened by the number of methods will be a performance indicator. The outputs will be achieved through accumulation and correlation of literature values of potential ethers. The solubility of the candidate ethers will be measured and correlated with physical properties to yield a correlation scheme. The environmental concerns will be dealt with by screening with microtox, degradation, and aquatic toxicity tests.

Funding
The average resources allocated for this project were $22k for fiscal year 2000–2001. An average 50% of these resources came from PERD funds, the rest came from other sources (A-Base). The average leverage quotient of total resources to PERD resources for this project was 2.0.

Strategic Intent 2 ·Strategic Direction 2

Strategic Direction 2 is to provide S&T to improve energy efficiency, reduce emissions, and provide economic benefits to Canada from next generation vehicles and systems.

Strategic Intent 2 ·Strategic Direction 2 ·Objective 2.2.2

The Development of Fuel Cell, Electric, and Hybrid Vehicle Components and their Supporting Infrastructures. (Multiplayer)

POL 2.2.2

The activities of the Fuel Cell, Electric (EV) and Hybrid Vehicles (HEV) POL are directed towards research and development of advanced electric vehicle (e.g., battery-powered, fuel cell-powered and hybrid-electric vehicles) technology. Expected outcomes of this POL include the development of market-ready components and systems, and supporting infrastructure including standards and the investigation of health, safety, and environmental issues. Government has an active role to play in developing technologies that can reduce GHG emissions from the transportation sector. In addition, a number of studies have shown that the electric vehicle technology being developed in this POL will reduce emissions of greenhouse gases and other pollution-causing compounds and will contribute to the goal of sustainable transportation and to more efficient use of available energy.

This POL combines work that was done previously by separate PERD working groups into one work program. It is a multi-player POL that is led by the NRCan's CANMET Energy Technology Centre (CETC). Other federal government POL participants receiving POL funding are NRCan, DND, TC, EC, and HC. NRC and IC participate in the program but do not receive funding. The POL is founded on research and development projects co-funded with industry, research organizations, and universities, as well as through cost-sharing arrangements at government laboratories. There are also a wide range of partners including: Agile Systems, Ballard Power Systems, Flywheel Energy Systems, Ford Motor Company, Global Thermoelectric, Groupe Enerstat, GSM, H-Power Canada, Hydrogenics, Inco, Lightyear, Noranda, Norvik, PMG Technology, Questor, RWDI, several public utilities, bus manufacturers, and Canada Post. Associations that have an interest in this POL are the Electric Vehicle Association of Canada and the Canadian Hydrogen Association.

The activities of the Fuel Cell, EV, and HEV POL include:

- investigation of promising new technologies;
- development and testing of lab and prototype components and systems (power sources, control systems, driveline technology), and field testing of pre-commercial prototypes; and
- investigation of health, safety, and environmental issues, to provide a knowledge base for the development of infrastructure (policies, standards and guidelines). Environment Canada participates in this activity.

POL 2.2.2 it scheduled to span 2000–2001 to 2002–2003. Average total funding per year for this POL is $8.46M. The proposed average PERD funding per year was $2.38M, for fiscal years 2000-2002. PERD funds were divided amongst the departments involved in this POL (see Table 9). For this POL, the average leverage quotient of total resources to PERD resources was 3.6.

Table 9
Percentage of PERD Funds for POL 2.2.2 Allocated to Each of the Departments

Department	Percentage of Funds (%)		
	2000–2001	2001–2002	2002–2003
NRCan	75.0	74.5	75.0
DND	10.9	10.8	10.9
TC	8.9	8.8	8.9
HC	3.4	3.4	3.4
EC	1.8	1.8	1.8
POL Evaluation	0	0.7	0

Environment Canada Projects for POL 2.2.2

Fuel-Cell Vehicle Life Cycle Emissions and Environmental Assessment

Project Manager: Russ Robinson

Overview
The project is over 50% completed and stems from previous PERD projects examining the environmental effects of electric vehicles. It is part of EC's Plan of Action for cleaner vehicles, engines, and fuels as part of the Federal Clean Air Strategy.

Objectives
The objective of this project is to explore the potential for using fuel cells in transportation applications and to assess the environmental implications associated with using this technology.

This research benefits Environment Canada since fuel cells are recognized as a viable minimum pollution power plant for the future. They are expected to enhance energy efficiency and reduce emissions including greenhouse gases, NOx, hydrocarbons, and particulate as well as creating job opportunities and economic growth in Canada.

Outputs and Methodology
Expected outputs from this project are assessments of the environmental impacts from the development of fuel cells and their supporting infrastructure in transportation applications. Outcomes from this work would be the potential adoption of standards and regulations and input to government policies and programs. Performance indicators include analysis of environmental risks and benefits of electric and fuel-cell vehicles. The outputs from this project will be achieved through the assessment of existing research in the area of fuel cells and assessments of the technical and operational feasibility of certain fuel-cell applications and the potential energy and air pollution savings and economic issues.

Funding
The average resources allocated for this project per fiscal year were $40k (1999–2000; 2000–2001). An average 62.5% of these resources came from PERD funds, the rest came from other sources (A-Base). The average leverage quotient of total resources to PERD resources for this project was 1.6.

Profiles by Strategic Intent

Transportation Sector

Development of Fuel Cell, Electric, and Hybrid Vehicles

Electric and Hybrid Vehicle Emmisions

Electric and Hybrid Vehicle Emmisions and Environmental Assessments

Project Manager: Russ Robinson

Overview
This project is a continuation of work examining the potential environmental benefits of electric and hybrid vehicles. It is part of EC's Plan of Action for cleaner vehicles, engines, and fuels as part of the Federal Clean Air Strategy.

Objectives
At least three vehicle manufacturers have plans to sell hybrid/electric vehicles in Canada. This new technology offers major climate change (fuel economy) and regulated emissions benefits. The technology, however, requires some changes to be made to testing protocols and the operability and emissions effects at low temperatures need to be assessed. While the hybrid vehicles have been designed and produced as direct equivalents to normal gasoline vehicles, it is recognized that their improved emissions and fuel consumption performance will be most evident in urban driving environments. The differing driving cycles, or components of complete cycles, will be studied to more thoroughly understand the nature of the environmental benefit of the new technology. The major benefits of hybrid/electric vehicles is improved fuel economy and reduced emissions including greenhouse gases, NOx, hydrocarbons, and particulate.

Outputs and Methodology
Outcomes from this work would be the potential adoption of standards and regulations and input to government policies and programs. Performance indicators include analysis of environmental benefits from hybrid/electric vehicles and a Canadian standard testing procedure for hybrid/electric vehicles.

The tasks to be accomplished for this project were to review current testing protocols for non-traditional drive systems, to establish and implement a testing program for a selection of hybrid/electric vehicles that would include various testing regimes and driving cycles to assess low-temperature emissions and operability, and to analyze the impact of the test procedure and establish a standard test procedure to govern future programs.

Funding
The average resources allocated for this project per fiscal year were $37k (1999–2000; 2000–2001). An average 67.6% of these resources came from PERD funds, the rest came from other sources (A-Base). The average leverage quotient of total resources to PERD resources for this project was 1.5.

Strategic Intent 2 · Strategic Direction 2 · Objective 2.2.4

The Optimization of the Energy Efficiency of Transportation Systems. (Multiplayer)

POL 2.2.4
This POL is intended to optimize transportation systems by using an integrated R&D strategy designed to improve energy efficiency and thereby reduce energy consumption and associated greenhouse gases (GHGs). Along with reductions in GHGs and regulated emissions, the strategy will result in a more competitive transportation industry and other economic benefits such as increased employment in industries providing technology to improve transportation systems.

There is a need to develop knowledge and technology to improve the interaction and integration of vehicles, operators, and infrastructure for the transfer of people and goods. The goal is to improve the efficiency of urban transportation, intermodal freight, and air transport, with a focus on information and communications technologies (e.g., sensors; communications; controls; vehicle, or vessel, location identification; navigation; and data storage, processing, and display).

POL activities include:

- *Urban Transportation Efficiency*—development of new knowledge, concepts, and technologies in urban traffic management and transit systems and supporting technologies and standards.
- *Intermodal Freight Efficiency*—route management in major marine shipping routes (e.g., reduced ship fuel consumption), port efficiency, and road/rail system efficiency. EC participates in this activity.
- *Air Transport Efficiency*—airport access and operations, and aircraft operations.
- *R&D on Future Opportunities*—early research on new technologies and approaches to expand the knowledge base.

POL 2.2.4 is led by Transport Canada. Other departments participating in the POL are TC, DFO, NRC, EC, and NRCan. Other partners include the Canadian Urban Transit Association, the Federation of Canadian Municipalities, the Canadian marine shipping industry represented through the Canadian Marine Advisory Committee, Oceanex Shipping Industry, the Port of Montreal, transit bus manufacturers, systems suppliers, Transport Quebec and several other provinces.

POL 2.2.4 it scheduled to span 2000–2001 to 2002–2003. Average total funding per year for this POL is $5.4M. The proposed average PERD funding per year was $2.38M for fiscal years 2000–2002. PERD funds were divided amongst the departments involved in this POL (see Table 10). For this POL, the average leverage quotient of total resources to PERD resources was 2.3.

Table 10
Percentage of PERD Funds for POL 2.2.4 Allocated to Each of the Departments

Department	Percentage of Funds (%)		
	2000–2001	2001–2002	2002–2003
TC	28.3	44.1	70.1
DFO	66.2	44.1	16.1
EC	4.7	6.3	6.3
NRC	0	2.9	2.9
NRCan	0	1.5	1.5
POL Management	0.8	1.1	1.1
POL Evaluation	0	0	2.1

Profiles by Strategic Intent

Transportation Sector

Energy Efficiency of Transportation Systems

St. Lawrence Routing Management Support Model

Environment Canada Projects for POL 2.2.4

The St. Lawrence Routing Management Support Model

Project Manager: Normand Michaud

Overview

This project is a followup on two separate PERD projects *Ice Forecast in the St. Lawrence System* (DFO) and *Improving Vessel Routing Methodologies in the St. Lawrence System* (EC). The projects were seen as ideal projects in terms of energy efficiency in the marine transportation system and were combined into one larger project called *The St. Lawrence Routing Management Support Model*. The Laurentian division of Canadian Coast Guard, responsible for safe and efficient navigation in the system, joined as a full partner and agreed to setting up a working prototype in their operational area.

This project is a joint project with DFO Sciences of the Laurentian Region and with the DFO Canadian Coast Guard (CCG) operations of the Laurentian Region. Partners will include the CCG Operations Centre, CCG Marine Communications and Traffic Services, DFO Science Maurice–Lamontagne Institute, the Canadian Hydraulics Centre of the National Research Council, Transport Quebec, EC's Marine Services and the Canadian marine shipping industry represented through the Canadian Marine Advisory Committee.

Objectives

The objectives of this project fit under the PERD context of energy efficiency and sustainable development through efficient transportation systems. This R&D initiative aims at determining optimal navigation routes in terms of fuel consumption and GHG reductions.

This project benefits EC in the following ways:

- The St. Lawrence transportation system produces about 2.7 Mt of CO_2 annually. A 5 to 10% reduction may lead to about 0.3 Mt (regional yearly savings estimated at 52 000 tons of fuel and 200 000 tons GHGs). Reductions country-wide will give about 3.6 Mt. Thus, this model promotes the reduction of GHGs.

- The routing model will contribute to water pollution prevention resulting from oil spills or other chemicals released at sea during accidents because the routing model will provide the optimal route in terms of fuel consumption, and also will provide alternate routes upon request. Severity conditions along the route will be provided, which will make for safer transits.

- The routing model improves marine transportation efficiency by improving the capability to predict environmental information over 0 to 48 hours. The Meteorological Service of Canada, a division of EC, is responsible for the provision of marine weather warnings to the marine community.

Outputs and Methodology
Output 1: Efficiency of routing system through the production of maps showing the most energy efficient routes. Performance indicators include information such as: the number of route changes; the number of vessels on/off route; response time to get routing advice to clients; and the number of pilots participating at workshops and courses.

Output 2: Safety/Severe weather and ice through the production of severity index maps, transit and index maps. Performance indicators include information such as the number of: severity index maps; vessels damaged; vessels beset in ice on/off route; maps showing areas of change in the ice and most energy efficient routes, as well as the type and severity of conditions.

Output 3: Coupled model development—upgrade the couple air-ice-ocean model. Performance indicators include information such as the number of upgrades in parameters and resolution, environmental variables, ship variables, and upgrade evaluation from users.

Output 4: Increase industry awareness through the use of brochures—including information on the number of industries complying with routing systems, client surveys, and CCG meetings.

Output 5: Sustainable development—for example, reports on transits including information on transit times, index maps, and the number of unexpected delays.

The system will apply various IT technologies to integrate actual weather, tidal, current, ice, water depth, wave and ship performance data to provide routing forecasts for transmission to and subsequent use by domestic and international ships. Trials and field experiments are carried out regularly using commercial ships operating in the St. Lawrence system. The power used by the ship, fuel consumption data, observational data on winds, waves, sea state, water temperature and ice are collected regularly, analyzed, assimilated and fed into the oceanic model (Coupled Atmospheric–Ocean–Ice model ran at DFO lab Maurice-Lamontagne). The prototype uses the results to provide transit and severity indexes, as well as fuel consumption and transit times for different classes of ships. The Canadian Coast Guard, along with funding and support from the stakeholders, is currently implementing this prototype system.

Funding
The average resources allocated for this project were $170k for fiscal year 2000–2001 (funds for 1999–2000 were not available). An average 65.3% of these resources came from PERD funds, the rest came from other sources (industry, other). The average leverage quotient of total resources to PERD resources for this project was 1.5.

Strategic Intent 3—Buildings and Communities Sector

Strategic Intent 3 is to reduce the overall energy intensity of Canada's buildings and community systems and, consequently, their associated GHG emissions while, at the same time, providing Canadian companies with potential economic opportunities.

Strategic Intent 3 · Strategic Direction 2

Strategic Direction 2 is to provide S&T to integrate energy services (supply and end use) in communities to reduce overall energy requirements, optimize the use of available resources, and reduce environmental impacts including GHG emissions.

Strategic Intent 3 · Strategic Direction 2 · Objective 3.2.1

The Establishment of Cost-effective Interconnections of Heat Sources and Sinks at the Community Level, which Promote the Use of Energy Appropriate to its Quality. (Multiplayer)

POL 3.2.1
The community energy systems (CES) POL focuses on technology needs that will allow the construction, operation, and management of thermal networks that link cost-effective and environmentally sound sources of heating and cooling capacity. It includes analytical and planning tools that provide the heating and cooling capacity and aims to improve efficiency and increase the use of renewable energy in communities.

The challenges to increasing the overall efficiency of community energy systems and reducing the impact of GHGs include: (1) understanding how CES projects can be implemented in a Canadian context and how technology can be made more cost-effective to compete in a lower cost energy price environment than exists in other countries where CES technology is broadly applied; and (2) adapting the technology to make use of the resources available to Canadians to meet the exigencies of communities [will lead to using industrial waste heat, renewable energy (primarily biomass)], or providing a host for highly efficient Combined Heat and Power or cogeneration plants.

The characteristics of projects in this POL include research in the following areas:

- community energy connections and systems components,
- systems modernization and modification to use low energy,
- technology transfer, training, and tools development,
- biomass based community energy systems, and
- load management through thermal energy storage.

EC is involved in activities focusing on thermal energy storage and related technologies. The expected outcome of the work is to provide existing district heating systems operators/managers with the ability to design and manage thermal storage systems for heating and cooling. Also, to increase the awareness of, and demand for a CES approach to energy efficiency, renewable energy use, and GHG reduction .

POL 3.2.1 is scheduled to span 2000–2001 to 2001–2002. Average total funding per year for this POL is $978k. The proposed average PERD funding per year was $585.3k, for fiscal years 1999–2002. PERD funds were divided amongst the departments involved in this POL (see Table 11). For this POL, the average leverage quotient of total resources to PERD resources was 1.7.

Table 11
Percentage of PERD Funds for POL 3.2.1 Allocated to Each of the Departments

Department	Percentage of Funds (%)		
	1999–2000*	2000–2001	2001–2002
NRCan	100	81.9	81.9
EC	0	13.0	13.0
PWGSC	0	5.2	5.2

*PERD activity organized differently for 1999–2000.

Environment Canada Projects for POL 3.2.1

Advanced Tools and Procedures for Implementing Thermal Energy Storage in Large Institutional Buildings, Commercial Buildings, and Community-oriented Applications

Project Manager: Frank Cruickshanks

Overview

This project stems from the PERD project *Advanced Tools and Procedures for Implementing Thermal Energy Storage in Large Institutional Buildings, Commercial Buildings, and Community-oriented Applications* designed to fill technology gaps that would make the implementation of thermal energy storage economically more attractive. This project involves applying the use of the same tools and techniques used in large institutional and commercial buildings in community-based buildings on a district heating and/or cooling system. Energy storage is a method to overcome the mismatch between energy supply and demand thereby optimizing such applications; thus, promoting improvements in energy efficiency in large buildings and industries.

This project is carried out in collaboration with the International Energy Agency (IEA) Implementing Agreement on Energy Conservation through Energy Storage (IEA–ECES). IEA–ECES Annexes (Teams) are collaborating on research initiatives such as HighTemperature Underground Thermal Energy Storage (UTES) for direct heating with thermal solar heat and waste heat from industry; proper placement, construction, maintenance and abandonment of boreholes and wells in UTES applications; the integration of conventional and renewable energy technologies with thermal energy storage for cooling in all climates; measurement tools and techniques, computer design models, environmental impact assessment procedures and engineering standards for UTES. R&D is generally dovetailed, with pilot projects such as the Sussex Hospital in New Brunswick, which is the first Aquifer Thermal Energy Storage (ATES) pilot project in a hospital application in North America. Other pilot projects include the new Agriculture Canada research facility in Agazzie, British Columbia, the Cape Jourimaine Nature Centre in New Brunswick, and a new community campus project in Halifax, Nova Scotia. In addition, this work is ongoing in partnerships with several universities, including Memorial University, Dalhousie University, Saint Mary's University, Acadia University, The Nova Scotia Agricultural College, The University of New Brunswick, Carleton University, Red Deer College, and Simon Fraser University.

Objectives

The research aims to assist the development of comprehensive tools, instruments, or methods to fill major technical gaps that make implementing Thermal Energy Storage (TES) a standard design option. Technology such as UTES improves energy efficiency by roughly 70% per application and subsequently, reduces GHG emissions. UTES eliminates the need for large cooling machines because cold from the natural environment is used to replace such machines and is renewable. High temperature UTES from waste heat or solar applications can be stored and used throughout the winter heating season thereby making solar thermal applications more reliable and efficient.

By storing waste heat from mechanical cooling processes and ambient cold from the natural environment, the work on UTES is encouraging significant improvements in energy efficiency in large buildings and communities and in the reduction in atmospheric emissions of GHG and ozone-depleting substances (ODS). This is consistent with Environment Canada's goal of providing Canadians with tools to prevent pollution and in developing green technologies and capacity that create social, economic, and environmental benefits. EC is recognized as a leader in this field, both nationally and internationally. This allows EC to bring technical expertise to the table when discussing collaborations, UTES, and also when discussing the integration and optimization

Profiles by Strategic Intent

Buildings and Communities Sector

Cost-effective Inter-connections of Heat Sources and Sinks

Thermal Energy Storage in Large Buildings

of renewable energy technologies using storage technologies. This work also is beneficial as it gives EC a presence in Atlantic Canada. In addition, EC benefits from IEA-ECES technology transfer and access to international specialists. Each pilot project reduces carbon dioxide emissions by 400 to 600 tonnes in commercial and institutional applications. Based on the work of IEA–ECES, EC in collaboration with PWGSC, were able to develop a CSA UTES Standard. Past work also has lead to the development of UTES Environmental Impact Assessment Procedures, which is now included as a checklist in the new CSA UTES Standard. Furthermore, the Thermal Response Evaluation Equipment, developed in close collaboration with Sweden, reduces effects on the subsurface and reduces borehole development costs by 10 to 30%.

Outputs and Methodology

- Tools and techniques for environmental screening of community-based UTES.
- Development of environmentally benign water treatment technologies for High Temperature UTES applications will be developed based on IEA expert advice and in conjunction with Annex 12 of the Implementing Agreement on Energy Conservation through Energy Storage (ECES) and field testing using a greenhouse facility.
- Development of a borehole thermal response test apparatus (testing and/or implementation of system). This involves field testing of various rock types for thermal response/thermal conductivity.
- Two-way technology transfer both nationally and internationally, related to IEA Annexes. This will be accomplished through developing seminars, workshops, conferences and training, and where possible, publishing reports, participating in IEA research and pilot projects.

Projects will include short- and medium-term R&D and technology transfer from Europe. Demonstration and/or prototype projects will be in collaboration with private industry and other market players. Results will be transferred through collaborations, workshops, seminars, conferences, reports, etc. Success will be measured by energy saved, emissions avoided (especially GHG emissions and CFC replacement), numbers and types of systems installed, the adoption of assessment tools and guidelines by stakeholders, and the integration of energy storage into various environmentally sustainable community-oriented energy projects.

Funding
The average resources allocated for this project per fiscal year were $223k (1999–2000; 2000–2001). An average 33.6% of these resources came from PERD funds, the rest came from other sources (A-Base, industry, NRSERC, NSAC, Sussex Hospital, other federal departments). The average leverage quotient of total resources to PERD resources for this project was 3.0.

Strategic Intent 3 · Strategic Direction 2 · Objective 3.2.3

Improvements in the Design and Integration of Energy, Transportation, Water and Waste Systems and Land Use to Permit Progressive, Sustainable Development of Communities.(Multiplayer)

POL 3.2.3

The Sustainable Community Energy Systems POL involves R&D activities into the relationship between energy use and community systems (e.g., land use, urban transportation systems, water and wastewater, buildings and urban waste management). The research focuses on energy and waste, sustainable community development, as well as examines the links between development patterns and private vehicle use. The fundamental goals are to reduce energy consumption, GHG emissions, and urban air pollution through four principal activity areas:

- *Integrate Energy and Community Systems R&D activities*: consult with key players in the field of community energy research to develop an integrated R&D strategy.
- *Energy and Community Systems*: reduce the overall intensity and energy-related environmental stress in the community through exploiting synergies between the energy system and the various components of the community system. EC participates in this activity.
- *Land Use, Access, and Mobility*: reduce automobile dependency, community design for fewer and shorter trips, increase utilization efficiency of transportation infrastructure.
- *Energy and Waste*: use synergies between waste management and energy systems to reduce waste quantities, energy intensity, and greenhouse gas emissions while extracting environmentally clean fuel and heat from the waste stream. EC participates in this activity.

POL 3.2.3 is scheduled to span 2000–2001 to 2001–2002. EC leads the Sustainable Community Energy Systems POL. Average total funding per year for this POL is $801.5k. The proposed average PERD funding per year was $376.1k, for fiscal years 2000–2002. PERD funds were divided amongst the departments involved in this POL (see Table 12). For this POL, the average leverage quotient of total resources to PERD resources was 2.1.

Table 12
Percentage of PERD Funds for POL 3.2.3 Allocated to Each of the Departments

Department	Percentage of Funds (%)	
	2000–2001	2001–2002
EC	65.2	64.6
CMHC	8.6	10.1
NRCan	7.2	8.4
Support for POL	14.4	16.9
POL Evaluation	4.5	0

Profiles by Strategic Intent

Buildings and Communities Sector

Integration of Energy, Transportation Water and Waste Systems and Land Use

Integrating Energy Systems

Environment Canada Projects for POL 3.2.3

Integrating Energy Systems for Sustainable Community Development

Project Manager: Claude Lefrançois

Overview
The first year of operation for the activity areas has focused on background research that will provide a foundation for setting the strategic direction necessary for achieving the POL objectives. Research includes an evaluation of the municipal use of models to assess urban energy use and air emissions. Several important lessons have been learned through a PERD partnership to assess the use of GIS to promote sustainable community development. In addition, POL committee members commissioned a study to explore the possible inclusion of Demand Management content in the *National Guide to Sustainable Municipal Infrastructure* being developed by the NRC and the FCM. If discussions with FCM and NRC are successful, as is anticipated, the development of content for the Infrastructure Guide will constitute a very effective partnership and area of investment for this POL.

Objectives
The objective is to contribute to improvements in the design and integration of energy, transportation, water and waste systems, and land use to permit progressive, sustainable development of communities. The outcomes include improved energy efficiency in communities resulting from improved land use and transportation planning. The current research involves two studies.

Outputs and Methodology
Overview of Study #1: The National Guide to Sustainable Municipal Infrastructure: Proposed Content on Demand Management Measures Scoping Report
The scoping report was developed to identify possible content on integrated land-use planning and energy demand management that could be included in a new *National Guide to Sustainable Municipal Infrastructure: Innovations and Best Practices*. This four-year, $12.5 million project (funding for the first two years is now confirmed) will be widely available to municipal planners, engineers, and decision-makers, and will include a "capacity building" component, with classroom instruction on best practices and use of the Guide. The project is being undertaken by the NRC, the FCM and their principal national partners—the CPWA and collaborators in municipal, provincial, trade, and professional associations.

The Infrastructure Guide will be Internet-based, and is intended to be a significant source book on planning for sustainability practices. At the present time, however, there are no plans to include a section in the Guide dealing specifically with planning, management, financing, and public education options related to managing the demand for infrastructure. The POL study, completed in May 2001, scopes the issue of planning and energy demand management in a municipal context and provides a framework for the inclusion of this issue in the National Guide to Sustainable Municipal Infrastructure. The proposed content-on-demand management measures are expected to be comprehensive enough to serve as a foundation for identifying potential pilot projects and further research areas.

Informal discussions are underway to secure the inclusion of energy demand management measures in the Infrastructure Guide. The scoping report, The National Guide to Sustainable Municipal Infrastructure: Proposed Content on Demand Management Measures will be provided to the FCM and NRC and a decision on its inclusion in the Infrastructure Guide or a follow-up study is expected by Fall, 2001.

Overview of Study #2: Analysis and Categorization of Sustainable Urban Planning Models
This study explored the current use of models developed to assist municipal planners in qualitative and/or quantitative assessment of factors affecting urban energy use and air emissions. The research approach included a survey sent to all member municipalities of the Partners for Climate Protection (PCP) program and interviews with leading practitioners.
The research indicated that there is no uniform approach to air emissions modelling in Canadian municipalities and that many practitioners were unaware of the models available to assess energy and air emission effects. In addition, municipalities often have difficulty accessing the data required to assess energy and air emission effects. The research suggested several requirements that should be considered in developing and using models including the need for: dedicated resources; data availability; model awareness; model credibility; and model simplicity.

The research has been documented and included in a guidebook, *Analysis and Categorization of Sustainable Urban Planning Models: A Guidebook for Canadian Municipalities.* The Guidebook has been distributed at workshops and conferences and is available to municipalities on the Federation of Canadian Municipalities Web site. Information provided in this guidebook should help municipalities understand the range of models available, and assist in evaluating their own needs and selecting an appropriate approach for their circumstances. This document, along with other material, will be used to initiate a discussion with municipalities on the identification of tools that can best support their efforts to reduce community energy use and emissions.

Funding
The resources allocated for this project for fiscal year 2000–2001 were $19.5k (funds were not available for fiscal year 1999–2000). Of these resources, 48.7% came from PERD funds, the rest came from other sources (A-Base). The leverage quotient of total resources to PERD resources for this project was 2.1.

Profiles by Strategic Intent

Buildings and Communities Sector

Integration of Energy, Transportation Water and Waste Systems and Land Use

Energy and Waste

Energy and Waste

Project Manager: Alain David

Overview
This activity area was established and funded as a separate R&D area before being included as an activity area in POL 3.2.3. It focuses on the integration of energy efficiency and energy utilization technologies into waste management systems.

Objectives
The research aims to make improvements in the design and integration of energy and waste systems. The outcomes resulting from this research include:

- more landfill gas is used to produce energy and emissions are accurately tracked;
- Canadian municipalities are better equipped to manage waste and recyclables in an energy efficient manner (e.g., energy consumption reductions and reduction in waste going to landfill).

Outputs and Methodology
The outputs of this work include:

- *Output #1*—report on testing and demonstration of new generation micro-turbines using landfill gas (LFG). Testing (e.g., pilot tests) has been completed at four LGF sites and optimized micro-turbines are under development; stack testing has been postponed.
- *Output #2*—updated integrated solid waste management (ISWM) model with additional modules updated and delivered to over 60 communities. A software model will be developed by industry with EC support. ISWM helps waste managers select strategies to manage wastes in a cost-effective and efficient manner. It is anticipated that municipalities will be able to use this model as a guidance tool.
- *Output #3*—demonstration project of advanced landfill technology. A report is to be developed by a team of academic and industry experts.

Funding
The resources allocated for this project for fiscal year 2000–2001 were $40k (funds were not available for fiscal year 1999–2000). 100% of these resources came from PERD funds.

Strategic Intent 4—Industry Sector

Strategic Intent 4 is to reduce the overall energy intensity of Canada's industrial sectors and, consequently, their associated GHG emissions while, at the same time, improving productivity and providing Canadian companies with potential economic opportunities.

Strategic Intent 4 ·Strategic Direction 3

Strategic Direction 3 is to provide S&T to advance generic energy-related technologies and processes to reduce energy intensity, particularly in industry, to achieve productivity gains and reduce GHG emissions and other wastes.

Strategic Intent 4 ·Strategic Direction 3 ·Objective 4.3.3

The Development of Advanced Technologies and Products for Heat Management and Separation Including High Efficiency Drying. (Multiplayer)

POL 4.3.3
The goal of this research is to decrease, in the mid- to long-term, the energy intensity and improve the productivity of selected industrial unit operations that are at the same time: (1) in widespread use; (2) energy intensive; and (3) amenable to wiser use of energy through technology and knowledge. The research focuses on four areas:

- separation of water from solids using drying technologies,
- separation of oil from solids using microwave-assisted processes (EC participates),
- separation of gas mixtures and the concentration of liquid solutions using membrane technologies, and
- management of cold.

The current PERD funding (2001–2002) for this POL is $1.364M which is divided between the participating departments EC, NRCan, and NRC. EC received 5.9% of the total PERD funding for fiscal year 2001–2002.

Environment Canada Projects for POL 4.3.3

Applications of Microwave-Assisted Processes (MAP) to Solvent-Less Synthesis and to Low Solvent, Energy-Efficient Extraction

Project Manager: Jocelyn Paré

Overview
This project stems from the PERD "extraction" project (1997–2000). Currently, the "extraction" portion of the program is funded under CCAF–TEAM (Climate Change Action Fund, Technology for Early Action Measures). This project focuses on MAP, as MAP processes validated to date have proven to be more energy efficient than other processing technologies. MAP processes are used to separate or extract liquids or dissolved solids into non-absorbing media and to provide new approaches for clean chemical synthesis. This process promotes energy efficiency because in a microwave heating is selective and localized rather than heating of the complete process system. In terms of processing energy only, applications of MAP consume, on average, 10% of the energy required by conventional processing technology.

The Federal Government has been a leader in R&D activities dealing with the use of microwave energy for selective processing for about twelve years. This expertise in microwave is basically exclusive to EC and in some ways EC acts as a catalyst in this field. As a result, several research activities have led to applications useful to the private sector. In particular, the end users for this application are the pharmaceutical industry, and the specialty chemicals and food ingredients sectors. The knowledge and experience acquired throughout this project will be transferable directly to the end user.

Objectives
The objectives of the project are to provide Canada's synthesis and extraction industrial sector with low solvent and low energy-consuming processes that will offer health, economic, and environmental benefits both nationally and globally while supporting sustainable development and reducing toxic substances and greenhouse gases. This project aims to further the development of the Government of Canada's patented MAP and to further use of microwave-assisted synthesis as an energy-efficient environmentally friendly industrial process for the synthesis industry.

These activities benefit EC because they fall into the industrial demonstration of pollution prevention work category required under CEPA and are in agreement with EC's objectives, as well as support the government's "good governance" objectives. It also supports EC's duty under the Fisheries Act by providing means to reduce or eliminate toxic substances release into wastewater effluents. The research also addresses government priorities, including:

- *Job Creation, Wealth Generation, and Competitiveness*
  This project will provide a cleaner, low-solvent or zero-solvent, more cost and energy-efficient extraction and chemical synthesis processes that will enhance the international competitiveness of the Canadian food and chemical sectors (thus, create or protect jobs in Canada), while providing increased market opportunities. There also is significant potential to further provide opportunities for yet new, unprotected applications of the use of microwaves in other industrial processing activities where selective heating would apply and further reduce overall energy consumption. To date, the licensing of the technology has already resulted in sales of hundreds of analytical systems and the creation of jobs while providing for more environmentally sustainable ways of conducting economically sound business.

- *Environmental Improvement*
  Comparative laboratory work has shown that MAP uses significantly less solvent (i.e., less toxic substances) than conventional processing technologies. Also, microwave-assisted synthesis generates fewer solvent wastes and consumes less energy thereby helping to reduce emissions of greenhouse gases and other pollutants from energy production.

- *Advancement of Knowledge*
  The use of microwaves to enhance biological, chemical, and physical processes is inherently innovative. Microwave-assisted synthesis is under accelerated development as evidenced in the increasing number of reports dealing with MAP and by the numerous patents granted in this area over the past five years. The expertise and experience of the team involved in this project is unique worldwide, and could provide Canada with an edge in the relatively unexplored area of novel atmospheric-pressure, solvent-less, microwave-assisted organic synthesis procedures.

Outputs and Methodology
The major deliverables are being achieved through laboratory studies and benchscale tests carried out at Environment Canada's Environmental Technology Centre (Ottawa) and Wastewater Technology Centre (Burlington). Specific outputs include:

1. Detailed energy requirement data for processing canola. Detailed dielectric properties of selected oleaginous materials (March, 2002).

2. Optimized operational parameters for (pilot-scale) canola solvent extraction (March, 2003).

3. Commissioned liquid propane pilot-plant ready to use (postponed to March, 2001).

4. A ready-to-be-implemented energy-efficient technology for the Canadian edible oil-processing industry (end of fiscal year 2002–2003).

EC has contributed to equipment development and design, and to determining the extent of applicability of technologies that are now commercially available for other applications within the general field of microwave-assisted processing. EC is involved in a major project under the CCTEAF involving microwave-assisted liquid-phase extraction. EC, through industrial partners, also is involved in commercializing some gas-phase extraction apparatus for laboratory application for which it has completed the proof-of-concept and prototype stages. The latter should be commercially available late 2002 or early 2003 via a Canada-France-Switzerland-Japan collaboration.

Funding
The average resources allocated for this project per fiscal year were $1.27M (1999–2000; 2000–2001). An average 6.3% of these resources came from PERD funds, the rest came from other sources (A-Base, industry). The average leverage quotient of total resources to PERD resources for this project was 15.9.

Strategic Intent 4 · Strategic Direction 3 · Objective 4.3.5

The Development of Low Energy Intensity Bioprocessing Technologies. (Single Player)

POL 4.3.5

This POL is a fairly new initiative focusing on one area of biotechnology research, specifically, the use of bioprocesses. In Canada, the use of bioprocesses for improved energy production, industrial energy efficiency, and production of less energy materials is impeded by scientific, regulatory, technical, environmental, financial, and commercial issues. There is a need for improved scientific knowledge and environmental research to advance the development of new bioprocess techniques. Achieving greater penetration of biology-based approaches into the existing Canadian infrastructure requires joint R&D efforts by government and industry to overcome impediments to utilization.

R&D in this area of biotechnology could contribute substantially to reducing fossil fuel consumption and GHG emissions; enhancing the overall efficiency of existing fossil fuel applications; improving industrial bioprocesses and energy efficiency; minimizing waste production; using biomass-based materials; and providing for cleaner fuels. Additional benefits are expected to accrue in future development of specific techniques for enhancing the ability of certain targeted biobased industrial processes for GHG reduction, improved energy efficiency and reduced non-renewable inputs.

Total funding per year for 1999–2000 and 2000–2001 for this POL was $218.8k. EC, the single player in this POL, received $100k in PERD funding per year. *Thus, for* this POL, the leverage quotient of total resources to PERD resources was 2.2.

Environment Canada Project for POL 4.3.5

Bioprocesses for Renewable Energy Production, and Improved Industrial Energy Efficiency in Canada

Project Manager: Terry McIntyre

Overview
This project is both complementary to and expected to be an integral component of two major federal government initiatives under Climate Change and the Life Sciences Agenda, as well as one major international initiative, Biotechnology for Cleaner Industrial Products and Processes, under the Organisation for Economic Cooperation and Development (OECD). On the federal government front, partnerships come from NRC, DFO, CFS, and HC. On the international front, partnership comes from nine different OECD countries.

This project aims to develop enhanced bioprocess applications for Canada's energy (cleaner coal and petroleum by removal of sulphur, biodiesel); mining (bioleaching and minerals biooxidation); pulp and paper (biobleaching, paper treatment with enzymes, paper recycling, and de-inking); and chemical (organic and amino acids, antibiotics, and industrial enzymes) sectors. Currently, there is increased support for bioprocesses worldwide; however, there is a need for improved scientific understanding in this area.

Objectives
The objective of this research is to use PERD/OERD funding to lever multi-stakeholder support for the development of bioproducts and processes to improve energy efficiency. The objectives are to assist in the identification, development, deployment, and increase user/public acceptance of biobased industrial products/processes that are less energy intensive, and have a smaller ecological footprint than existing physical/chemical/thermal techniques. The industry sectors targeted for this work are the chemical and plastics, forestry, mining, food and beverage, and energy sectors which account for 40% of total industrial energy use in Canada; 60% of industrial greenhouse gas emissions; and 50% of those industrial pollutants listed on EC's National Pollutant Release Inventory.

The POL Bioprocess for Energy Efficiency Working Group has targeted the following areas as current and anticipated future priorities:

- transgenic short-rotation crops for biopower
- improving photosynthetic efficiency
- improved oilseed crops and microorganisms
- direct/indirect production of biohydrogen
- use of novel micro-organisms from extreme environments
- improved enzymatic techniques for biomass waste conversion to biofuels
- genetic engineering of fermentation production strains
- development of biochips
- microbial enhanced oil recovery
- bioupgrading
- technologies for gas and water-waste streams

The benefits to EC include environmental benefits and improved scientific knowledge in the area of biotechnology. Bioprocesses minimize environmental damage from current industrial practices in a number of ways such as the development of new bioprocesses to diminish waste production of end-of-pipe processes using micro-organisms to purify waste streams. In addition, the use of

Profiles by Strategic Intent

Industry Sector

Low Energy Intensity Bioprocessing Technologies

Renewable Energy Production

bioprocesses has been shown to be an effective method to slow the buildup of green house gases. At present, their use is underutilized in Canada. This work intends to help advance the knowledge and use of bioprocesses in Canada. This technology will lead to a greater reliance upon renewable and biology-based alternatives rather than conventional sources of fossil fuels that contribute to GHG production. Bioproducts and bioprocesses also provide a basis for industrial sustainability in Canada.

Outputs and Methodology
The outputs to date include a:

- comprehensive industrial sector analysis for areas where biobased processes can be expected to reduce energy use, minimize, and reduce GHG production, and lessen environmental effects;
- detailed global literature review of bioproduct and process development information;
- global assessment of the opportunities and challenges associated with moving towards a biobased economy;
- candidate list of biobased products and processes that could be deployed in representative Canadian industrial sectors;
- draft framework for technology assessment of biobased products for sustainability;
- citizen primer on biobased economy;
- levered the generation of 24 biobased life-cycle assessments from nine different OECD countries; and,
- generated empirical data necessary to develop two substantive proposals for Canada's Innovation Agenda and Canadian Biotechnology Strategy.

Outputs will be largely achieved through technology assessment, development, deployment, verification, receptor/public acceptance, and ultimately integration as part of the day-to-day operations of the targeted industrial sectors.

Funding
The average resources allocated for this project per fiscal year were $218.8k (1999–2000; 2000–2001). An average 45.7% of these resources came from PERD funds, the rest came from other sources (A-Base, industry, other). The average leverage quotient of total resources to PERD resources for this project was 2.2.

Strategic Intent 5—Electricity Sector

Strategic Intent 5 is to reduce the environmental impacts of Canada's electricity infrastructure, particularly greenhouse gases, through alternative electric power generation, increased efficiency of fossil-fueled plants, and strategies to capture and manage emissions.

Strategic Intent 5 · Strategic Direction 1

Strategic Direction 1 is to provide S&T to increase the proportion of Canada's electricity supply from renewables and distributed systems which offer improved system integration and reduced environmental impacts. (R&D activities in this area will exclusively address generic technological issues whose applications are not related to communities, buildings, and industry).

Strategic Intent 5 · Strategic Direction 1 · Objective 5.1.1

Improving the Economics and Efficiency of Conversion of Renewable Energy to Electricity Including Related Storage, Hybrid, and Systems Technologies. (Multiplayer)

POL 5.1.1

The Federal government has recognized the potential role that electricity generation from renewable energy technologies can play in achieving sustainable development of renewable energy options and adopted favorable policies for their development and commercialization. Renewable energy is viewed as a means to advance the economic, environmental, and social agenda of the government; however, renewable energy technologies still suffer from high production costs because they are not in a position to exploit the economy of large-scale production. The technologies also lack the infrastructure of codes, standards, and training tools needed in system selection, installation, and operation and maintenance. Additional constraints include low electricity buy-back rates, surplus capacity, and lack of familiarity with the reliability and performance of renewable energy systems. The current POL is designed to address these constraints and to accelerate the expansion of electrical generation from renewable and sustainable sources. The main components of this program are wind energy technology development, small hydro technologies, biomass conversion to electricity, and infrastructure support activities for all renewable energy technologies including photovoltaics and others.

NRCan's Energy Technology Centre leads the POL 5.1.1; EC is involved in the Resource Assessment component (i.e., wind and solar resource assessment) which comprises one of the Infrastructure Support projects.

POL 5.1.1 is scheduled to span 2000–2001 to 2001–2002. Average total funding per year for this POL is $4.857M. The proposed average PERD funding per year was $1.3445M, for fiscal years 2000–2002. PERD funds were divided amongst the departments involved in this POL (see Table 13). For this POL, the average leverage quotient of total resources to PERD resources was 3.6.

Table 13
Percentage of PERD Funds for POL 5.1.1 Allocated to Each of the Departments

Department	Percentage of Funds (%)	
	2000–2001	2001–2002
NRCan	53.1	55.9
EC	23.7	24.3
DFO	18.2	19.8
POL Evaluation	5.0	0.0

Environment Canada Projects for POL 5.1.1

Solar and Wind Energy Resource Assessment

Project Manager: Robert Morris

Overview
This project stems from the previous PERD project *Solar and Wind Energy Resource Assessment*. The project comprises a number of activities concerned with acquiring information on the solar and wind energy resources to assist the development of technologies. This task is concerned with improving wind and solar energy resource assessment capability, primarily through development of observing instrumentation and development of methods to estimate solar and wind resources from existing information. Benefits from this work are shared by other renewable energy POLs including the Buildings and Communities POL. The Environment Canada component is broken down into three activities: *Wind Modelling and Forecasting*, *Solar Radiation Measurement Technology*, and *Solar Radiation Resource Assessment*.

Objective
The objective is to develop information, instruments, and improved tools to increase the knowledge of wind and solar resource assessments. This research benefits EC because by improving the economics and efficiency of renewable energy to electricity technologies (POL objective), Canada can increase its low or non-CO_2-emitting energy supply options to address the Kyoto targets. Canadian companies involved in renewable energy can contribute to employment, exports, and other economic objectives. This research also addresses issues such as public safety and air quality through the use of mesoscale models for short-term forecasting of various weather elements. Finally, local implementation of renewable energy projects can promote energy self-reliance while providing jobs and other benefits.

Outputs and methodology
Wind Modelling and Forecasting—The Meteorological Research Branch of EC conducts this task. It deals with improving the wind modelling capability of the EC operational meteorological models, fine-scale wind data sets for climatological analysis (for detailed wind assessment) and for developing automated wind speed forecasts for arbitrary locations in support of operational grid-connected wind energy projects. The R&D in 2000–2001 will focus on comparing the medium-resolution (15 km) operational model results with high-resolution (0–10 km) research model results, and to improve the numerical representation of boundary layer physics in the operational model. Field trials of wind energy resource forecasts and assessment using the output of EC numerical weather prediction models at an operational wind energy farm will be conducted. The outputs research include:

- Use of the medium-scale Global Environmental model (GEM) to map wind resource at 24km resolution for a 5-year period for the United States and Canada at 50 km above ground (report published in National Geographic).

- Development of a plan to use the MC2 (EC's model) mesoscale model for a regional wind resource atlas and allowing the model to proceed on desktop workstations.

- Production of a prototype, detailed wind resource atlas for at least on region (Gaspé, Quebec) by applying the MC2 mesoscale model (by late 2001).

Solar Radiation Measurement Technology—This task concerns the improvement of solar radiation observation technology to improve the accuracy of solar measurements. This activity anticipated improving the use of both a blackbody calibrator and a cold chamber (results

submitted to the *Journal of Atmospheric and Oceanic Technology* 2001–2002) to investigate the performance of standard solar radiation instruments used in the Canadian solar radiation network operated by Environment Canada. The work on the new black-body calibrator was delayed this year; however, the cold chamber work proceeded and results from the testing led to new calibration procedures. This work is lead by EC's National Atmospheric Radiation Centre and follows on from previous International Energy Agency (IEA) agreements related research.

Solar Radiation Resource Assessment—This task is lead by EC's Climate and Water Products Division and deals with the development of solar energy resource information compiled from standard meteorological observations. The support for EC participation in ASHRAE (American Society of Heating, Refrigerating, and Air Engineers) activities continues under this activity. ASHRAE funds research concerned with estimating the solar resource (in this case for use in building energy calculations). An ASHRAE project nearing completion will provide solar radiation estimates for more than 200 international locations (outside the United States and Canada). In addition, ASHRAE has approved and is requesting bids for a project to develop and implement new algorithms to estimate solar radiation from the Automated Weather Observation Systems. Previous PERD research helped to develop models to estimate the solar resource from the hourly manned observations.

Overall, the target of improved wind forecasts is about 10% achieved. The target of a regional wind atlas method (unreported in the POL plan, but implemented because of a new approach allowing its implementation on desktop computers, and significantly more requests from the wind energy sector) is about 10% achieved. Work on a solar radiation assessment test pilot plan is about 10% achieved.

Funding
The average resources allocated for this project per fiscal year were $117k for 2000–2001 (funds for 1999–2000 were not available). An average 59.8% of these resources came from PERD funds, the rest came from other sources (A-Base). The average leverage quotient of total resources to PERD resources for this project was 1.7.

Strategic Intent 5 · Strategic Direction 2

Strategic Direction 2 is to provide S&T to reduce emissions and the associated environmental impacts from centralized, combustion-based electric power generation systems.

Strategic Intent 5 · Strategic Direction 2 · Objective 5.2.1

The Characterization of Canadian Fuels and their Emissions (COFE) for More Efficient and Environmentally Benign Electricity Generation. (Multiplayer)

POL 5.2.1
This POL is a grouping of both independent and coordinated research initiatives from various federal departments that involve the characterization of Canadian fuels and their emissions for more efficient and environmentally benign electricity generation. Coal constitutes 80% of Canada's endowment of fossil energy and currently provides 19% of Canada's electricity. In the future, Canada's coal deposits offer an immense potential as an alternative source to natural gas. The improved understanding of the environmental impacts of energy generation is important as it affects the health and well-being of Canadians and contributes to the global impacts of fossil fuel use. A national knowledge base on the suitability of Canada's coals as an alternative energy source will facilitate the maintenance of the competitive position of Canada's energy-intensive industrial base in international markets while minimizing environmental impacts. Furthermore, a national knowledge base on the characteristics of emissions from existing generation facilities will ensure the development of appropriate regulations and mitigative technology to minimize the health risks to Canadians.
The activities for this POL objective include:

- *Fuel characterization for sustainable production and environmental risk assessment*—Characterization of Canadian coal fuels that will be used for thermal and other advanced methods of generating electricity in terms of elemental contaminants, technological characteristics, and environmental constraints to development.

- *Resource management technology development*—Integration of fuel characterization and emissions information within modern computer-based analysis, assessment, and reporting systems for interpretation and delivery to clients and stakeholders.

- *Emissions characterization and environmental monitoring*—The characterization of emissions from Canada's major centralized combustion-based electrical power generation plants.

The goal of these activities is the reduction of environmental impacts of Canada's electric infrastructure and adoption of appropriate advanced end use technologies to increase Canada's international competitiveness.

POL 5.2.1 is scheduled to span 2000–2001 to 2002–2003. Average total funding per year for this POL is $911.3k. The proposed average PERD funding per year was $741k, for fiscal years 2000–2003. PERD funds were divided amongst the departments involved in this POL (see Table 14). For this POL, the average leverage quotient of total resources to PERD resources was 1.2.

Table 14
Percentage of PERD Funds for POL 5.2.1 Allocated to Each of the Departments

Department	Percentage of Funds (%)		
	2000–2001	2001–2002	2002–2003
NRCan	86.9	83.3	86.9
EC	13.1	12.7	13.1
POL Evaluation	0	4.0	0

Profiles by Strategic Intent

Electricity Sector

Characterization of Canadian Fuels and their Emissions

Contaminants in Coal

Environment Canada Projects for POL 5.2.1

Environmental Contaminants in Coal and Coal By-products

Project Manager: Don Rose

Overview
This project stems from research initiatives that began in the early 1980s. EC's PERD program has been extensively involved in research that is aimed at understanding the environmental and health impacts of fossil fuel electricity generation. The current work continues this research by attempting to identify ways of preventing, minimizing, or mitigating the health and environmental impacts of fossil fuel electricity generating operations. EC and the Geological Survey of Canada have collaborated to put forth a multiyear plan to measure, analyze, and characterize the fleet of Canadian fossil-fired electricity generating units. EC participates specifically in the emissions characterization and environmental monitoring activity of the overall program. The primary focus of the research is pollution prevention and environmental/health protection.

Objectives
The objective is to characterize contaminants (e.g., metals, halides, PAHs, and other potentially toxic substances) in coal feedstocks, stack emissions, and in the vicinity of major power plants.

Research in this area allows EC to better understand the characteristics of ashes and substances emitted in power plant stack gases. Also, it provides a better understanding of the contributions of these sources to the provincial and national inventories. This knowledge allows policy makers to focus on key areas and sources to help develop efficient and cost-effective measures for pollution prevention and reduction.

Outputs and Methodology
The output of this work involves emissions characterization and environmental monitoring to produce a database, to conduct analysis and interpretation of As, Cr, Hg, and Ni speciation, PAHs, particulate matter (PM) and other environmental contaminants from six major power plants. The performance indicators include sample collection (e.g., milled coal, power plant ash, and stack particles/gases), laboratory analysis, and interpretation for all six power plants. Stakeholders can use this information to assess the environmental impact of emissions from centralized combustion-based electric power systems for specific fuel characteristics and combustion technologies.

The methods involve an *in-situ* analysis of feedstocks, stack sampling, near plant precipitate sampling to help develop a contaminant knowledge base in coal feedstocks, in emissions from power plants stacks, and in the vicinity of power plants.

Funding
The average resources allocated for this project per fiscal year were $259k for 2000–2001 (funds for 1999–2000 were not available). An average 37.5% of these resources came from PERD funds, the rest came from other sources (Geological Survey of Canada). The average leverage quotient of total resources to PERD resources for this project was 2.7.

Strategic Intent 5 ·Strategic Direction 2 ·Objective 5.2.2

The Conversion of Fossil Fuels to Electricity More Efficiently with Ultra-low Environmental Emissions. (Multiplayer)

POL 5.2.2

The POL focuses on improving thermal efficiencies and reducing GHG emissions from existing generating stations, determining potentially hazardous substances in combustion residues, and evaluating advanced, high efficiency, clean combustion cycles for electricity. The goal is to provide utilities and supporting industries, including boiler and burner manufacturers, instrumentation and control companies, consulting engineers, environmental abatement equipment fabricators and regulatory bodies with the S&T needed to economically and effectively improve electricity generation performance and to reduce emissions per unit output. This POL is designed to provide technologies that can be retrofitted to existing units over the short-to medium-term, evaluate feasibility, and accelerate the deployment of advanced clean combustion cycles and equipment over the long-term.

The three areas of activities include:

- *Upgrading of existing technologies*—Improved thermal efficiencies and reduced GHG emissions from existing generating stations.
- *Hazardous combustion residues*—Determination of potentially hazardous substances in combustion residues. EC participates in this activity.
- *Advanced electricity cycles*—Advanced, high-efficiency, clean combustion cycles for electricity.

All activities within the POL for the clean and efficient conversion of fuels to electricity for large utility applications are carried out in partnership with Canadian and foreign utilities, government departments, research organizations, and/or boiler manufacturers in Canada and abroad. This POL targets conventional and advanced electricity cycles involving R&D initiatives ranging from mechanistic studies and pilot-scale experiments to numerical analysis and technology transfer.

POL 5.2.2 is scheduled to span 2000–2001 to 2002–2003. Average total funding per year for this POL is $3.29M. The proposed average PERD funding per year was $1.98M, for fiscal years 2000–2003. PERD funds were divided amongst the departments involved in this POL (see Table 15). For this POL, the average leverage quotient of total resources to PERD resources was 1.7.

Table 15
Percentage of PERD Funds for POL 5.2.2 Allocated to Each of the Departments

Department	Percentage of Funds (%)		
	2000–2001	2001–2002	2002–2003
NRCan	85.2	85.2	84.7
EC	14.8	14.8	15.3

Profiles by Strategic Intent

Electricity Sector

Conversion of Fossil Fuels to Electricity

Pollution from Stationary Combustion Sources

Environment Canada Projects for POL 5.2.2

Prevention, Control, and Mitigation of Pollution from Stationary Combustion Sources

Project Manager: Don Rose

Overview

This research stems from the PERD project *Prevention, Control, and Mitigation of Pollution from Stationary Combustion Sources* aimed at understanding the environmental and health impacts of fossil fuel electricity generation. This work attempts to identify means of preventing, minimizing, or mitigating the health and environmental impacts of fossil fuel electricity generating operations. The primary focus is on pollution prevention and environmental/health protection. The research is carried out in collaboration with federal agencies (NRCan, CANMET Energy Technology Centre, the GSC, HC), the Canadian Electricity Association, and industry.

This project is comprised of several individual elements:

- *A Study of the Application of Integrated Gasification Combined Cycle (IGCC) in Canada*. This study is carried out through partnerships between CANMET Energy Technology Centre and EC. The purpose of the study is to assess alternative technologies for utilization of various fuel resources for electricity generation while at the same time addressing multiple pollutants.

- *Fine Particulate Emissions Measurement and Characterization from Utility Boilers*. The partners include: CANMET Energy Technology Centre, TransAlta Utility Corp., Ontario Power Generation Inc., and Environment Canada. The project aims to develop a method for measuring and analyzing fine PM emissions which account for primary particulate emitted together with the secondary PM formed from precursors in the flue gases.

- *Atmospheric Time-of-Flight Laser Ablation Mass Spectrometry (ATOFLAMS) for PM Measurement and Characterization*. The partners for this project include the University of Toronto and EC. The purpose is to develop a technology for measuring, analyzing, and characterizing the PM fractions in real-time streams of ambient air and to be able to determine the proportions of ambient PM that are contributed by various sources.

Objectives

The objectives are to: (1) assess the viability of potentially more efficient generation technologies [such as integrated gasification combined cycle (IGCC)]; (2) determine the environmental impacts of different generation technologies; (3) more accurately measure and characterize emissions (such as PM); and, (4) apportion ambient PM loadings to various sources.

EC recognizes that trace emissions of ultrafine particles, toxic organics, and hazardous trace elements from powerstation stacks are a priority concern for human health and the environment. Research in these areas allows EC to better understand the potential options of CO_2 sequestration in order to help address climate change concerns. The research assesses the feasibility of viability of potentially more efficient electricity generation technologies and helps promote a better understanding of pollutant emissions from the different sources, the interactions of these pollutants in the atmosphere, and the contributions of the various emissions sources to the ambient loadings. This knowledge allows EC to focus on key areas and sources in order to develop efficient and cost-effective measures for pollution prevention and reduction. The

research also addresses the government priorities including environmental and health protection, development of standards and codes, the advancement of knowledge, and job creation. In addition, the research fully complies with EC's PERD mandate "to conduct the R&D which will ensure the economic viability and environmental sustainability of Canada's energy economy, in keeping with the departments three key business lines."

Outputs and Methodology
The major deliverables encompass a more complete knowledge base and a better understanding of the quantification, fate, and environmental/health impacts of emissions from combustion systems. There are two program outputs:

- Computer simulation of biomass gasification for co-firing with pulverized coal. Performance indicators will be the number of cases analyzed; EC anticipates complete verification and feasibility studies by 2003.

- Techno–economic evaluations of IGCC. IGCC is a combustion technology that has been in demonstration and operation in the United States, Europe, and Japan. IGCC offers a powerful solution to use coal for electricity generation while keeping atmospheric emissions lower than traditional technologies; however, some of the aspects of this promising technology still need to be investigated before being widely accepted. This research will continue the investigation of IGCC. Performance indicators are the number of cases analyzed; EC anticipates the completion of three analyses by 2003.

The outputs will be achieved through modification and improvement of a computer model for simulation of gasification of biomass and coals. Following this, lab studies will be conducted in a pilot-scale modified entrained flow gasifier for firing fossil fuels and a pilot-scale atmospheric fluidized bed gasifier for firing biomass.

Funding
The average resources allocated for this project per fiscal year were $758.9k (1999–2000; 2000–2001). An average 39.5% of these resources came from PERD funds, the rest came from other sources (industry, other). The average leverage quotient of total resources to PERD resources for this project was 2.5.

Strategic Intent 5 ·Strategic Direction 2 ·Objective 5.2.3

The Capture, Treatment, Transport, Use and Storage of CO_2 from Large Point Sources. (Multiplayer)

POL 5.2.3
The CO_2 Capture and Storage POL is designed to include research and development activities that involve the capture, treatment, transport, use and/or storage of carbon dioxide (CO_2) from large point sources for the purpose of reducing greenhouse gas emissions to the atmosphere. Work in this area is ongoing around the world, with the IEA and the United States Department of Energy (USDOE) as key players.

The POL involves the development of new technologies for the combustion and gasification of fossil fuels that permit cost-effective CO_2 capture as well as developing and testing new ways of capturing CO_2 and determining how they can be integrated into existing systems. The research also involves developing systems studies and pilot projects for CO_2 collection and distribution networks, including pipeline transportation systems. In addition, it aims at developing cost-effective technology to use and sequester CO_2 in enhanced oil recovery and coalbed methane operations, and to sequester CO_2 in oceans and in geological formations such as deep saline aquifers, depleted oil and gas fields, and mineral deposits. Finally, the research will characterize the storage potential of oceans and geological reservoirs and the environmental impact of CO_2 stored in these reservoirs.

Projects include:

- Advanced Combustion Process Design and Pollution Abatement for CO_2 Capture and Sequestration (CANMET Energy Technology Centre, NRCan)
- Modelling, Development and Process Integration of a Cryogenic/Condensor Separator for CO_2 purification and capture (CANMET Energy Technology Centre, NRCan)
- Sustainable Development of Coalbed Methane (CBM) (EC)
- International CO_2 Ocean Disposal/Sequestration Experiment (Fisheries and Oceans Canada)
- CO_2 Storage Capacity of Canadian Coal Seams (GSC)

POL 5.2.3 is scheduled to span 2000–2001 to 2002–2003. Average total funding per year for this POL is $2.9334M. The proposed average PERD funding per year was $1.034M, for fiscal years 2000–2003. PERD funds were divided amongst the departments involved in this POL (see Table 16. For this POL, the average leverage quotient of total resources to PERD resources was 2.8.

Table 16
Percentage of PERD Funds for POL 5.2.3 Allocated to Each of the Departments

Department	Percentage of Funds (%)		
	2000–2001	2001–2002	2002–2003
NRCan	69.2	70.0	75.3
EC	23.9	20.6	16.8
DFO	6.9	9.4	7.9

Profiles by Strategic Intent

Electricity Sector

Capture, Treatment, Transport, Use and Storage of CO_2

Sustainable Development of Coalbed Methane

Environment Canada Projects for POL 5.2.3

Sustainable Development of Coalbed Methane; A Life-Cycle Approach to Production of Fossil Energy

Project Manager: Bill Reynen

Overview
Initiated in 1996, this work stems from the PERD project *Sustainable Development of Coalbed Methane; A Life-Cycle Approach to Production of Fossil Energy* in which Phases 1 and 2 were completed in 1998. The earlier study, conducted under the direction of Dr. William Gunter and by the staff of the Alberta Research Council, provided pilot-scale results. In 1998, a single well micro-pilot test of Mannville coal seams in the Fenn/Big Valley area of Alberta was completed. During Phase 2, pure CO_2 injection was tested and it was found that excellent sweep characteristics for the CBM reservoir could be obtained.

This research is carried out in partnership with a range of industry and government partners such as the Alberta Research Council, Alberta Department of Energy, Mobil Oil Canada, TransAlta Utilities Corporation, EC/PERD, PetroCanada Resources, EPCOR (formerly Edmonton Power), Air Liquide Canada, and the Climate Change Action Fund. Other new partners include Suncor Energy, PanCanadian Petroleum, and the CAPP. The U.S Department of Energy also contributes to the project. Other partners include Gulf Canada, Burlington Resources, Canadian Fracmaster, BP Exploration (Alaska) Inc., and the Department of Trade and Industry (United Kingdom).

Objectives
The main objective is to develop technology that will allow development of Canada's CBM resources while reducing CO_2 emissions to the atmosphere.

The research benefits EC by addressing the following government priorities:

- *Stabilization of GHG Emissions and Environmental Protection*
  Environment Canada plays a key role in efforts to help stabilize GHG emissions. The study would develop technologies for the capture and disposal of carbon dioxide following its formation. Deep coal beds in Alberta represent large, natural 'sinks' suitable for CO_2 disposal in an environmentally acceptable manner. Development of technologies to use these emissions for the purpose of enhancing methane recovery from these coal beds would be the primary target of the proposed study.

- *Technology Transfer Opportunities and Advancement of Knowledge*
  The opportunities for technology transfer related to this project are enormous. Coalbed methane (CBM) and the use of gas injection methods are the early stages of development. Except for several experimental pilots in the United States, all the CBM production in the world is primary (i.e., natural drive). Currently, there are four CBM-producing wells in Canada (operated by Gulf Canada in the Fenn/Big Valley area of Alberta). This study would provide valuable technical information that could be applied in Canada and internationally. This is of particular significance as no two sedimentary basins are alike, and differences in burial history, tectonic regime, and regional flow pattern of formation water, among other properties, would determine the extent of CO_2 disposal and quantities of methane released from deep coal beds.

- *Job Creation, Economic Development, and Wealth Generation*
  The study will make a significant contribution to the government goals of GHG reduction, energy efficiency, and sustainable development. Canadian industry could then market and export the technology developed to other coal-producing nations interested in abatement of emissions. Drilling activity for CBM production will spur economic activity not only in Alberta, but also in other parts of Canada where CBM resources have been identified (e.g., BC, NS,and PEI). This activity would result in economic development and the need for specialized labour, thus creating jobs and increasing government revenues from royalties and taxation.

Outputs and methodology
The major deliverables (based on results from field and pilot-scale tests) include:

- *Conducting the first CBM-producing five-spot pilot in Canada (1999–2000) to evaluate primary CBM recovery rates for Canadian coals.* The project involved drilling and completing five wells to evaluate horizontal drilling technologies.

- *Complete and demonstrate for the operation of the first industrial-scale O_2/CO_2 recycle power plant to supply energy and CO_2 at the CBM pilot site during 2000–2001.* The process results in energy production with a dry flue gas composition of nearly 95 to 99% pure CO_2 that requires no further processing for direct injection into the well. For future applications, in well sites with CO_2 breakthrough accompanying the produced methane, the technology also permits the direct combustion of CH_4/CO_2 mixtures in the power plant without the need for further processing. The development of this unit will provide an intermediate scaling point for experimental pilot-plant data, before it is implemented in the future on much larger scale utility power plant projects. The process reduces the estimated energy penalty for CO_2 capture from flue gases produced by conventional power plants by at least 50% with corresponding savings in both the capital and operating costs. The process will result in the development of the world's first O_2/CO_2 recycle power plant and the new advanced power generation cycles for fossil fuel utilisation with zero net CO_2 emissions.

- *In 2001–2002, the CO_2 injection process is tested and proved for CO_2-gas injection scheme to enhance methane production and disposal of CO_2 in the coal beds.* The technology will be optimized and tested for production of high-energy fuel from deep coalbeds and disposal of CO_2 (equivalent to that from use of the methane) into the same coalbeds.

- *In 2002–2003, the development and use of computer tools for targeting potential CBM reservoirs in Alberta.* In the short-term, the goal is to have information available in a readily accessible form for location of potential high value CBM reservoirs in the sedimentary basin. In the long-term, software format for expanding the database exists. This ongoing work is necessary as a precursor to successful exploitation of CBM in Alberta and evaluation of the total capacity of Alberta's CBM reservoirs for CO_2 sequestration.

Funding
The average resources allocated for this project per fiscal year were $1.8195M (1999–2000; 2000–2001). An average 12.0% of these resources came from PERD funds, the rest came from other sources (industry, other). The average leverage quotient of total resources to PERD resources for this project was 8.4.

Strategic Intent 6—Climate Sector

Strategic Intent 6 is to minimize the negative impacts of climate change on the Canadian energy sector.

Strategic Intent 6 · Strategic Direction 1

Strategic Direction 1 is to provide S&T to support the Canadian energy sector's response to the impacts of climate change.

Strategic Intent 6 · Strategic Direction 1 · Objective 6.1.1

The Development of a Better Understanding of the Impacts of Climate Change on the Energy Sector, Improvement in the Forecasting of Those Impacts, and the Development of Some Possible Response Strategies. (Multiplayer)

POL 6.1.1
Climate change due to increases in greenhouse gases in the atmosphere will have significant implications for Canada's energy sector. Changes in temperatures, rise in sea level, sea ice regimes, land stability, hydrological cycles, wind regimes, and cloud cover as well as changes in extreme events will affect energy production, transmission, distribution, and demand. Changes are also expected in seasonal heating and cooling requirements in North America, which will result in changes in demand on the continent. A significant amount of climate change research is being conducted in Canada to enhance our understanding of the climate system and to improve our ability to forecast future climate. The federal government has developed the expertise and the capacity to work in this area because it is a public good issue.

The Climate Change Impacts on the Energy Sector POL (CCIES) POL involves several federal agencies and departments involved with providing S&T in support of Canada's energy sector. Participating organizations include EC, DFO, NRCan, and INAC). Participating organizations collaborate with other POL plans and climate research programs within the participating organizations and the academic community. Research projects within this POL will be undertaken by research teams that are also participating in international climate and global change research under the World Climate Research Program (WCRP) and the International Geosphere-Biosphere Program (IGBP). Thus Arctic and sea ice programs will be coordinated with the Arctic Climate System Study (ACSYS), water resources programs with the Global Energy and Water Cycle Experiment (GEWEX), climate change simulations and regional climate modeling with the Climate Variability and Prediction Program (CLIVAR), and the working group on Coupled Climate Modelling (WGCCM). These connections will enable results of the POL research to be assessed internationally through the regular assessments of the Intergovernmental Panel on Climate Change (IPCC).

The CCIES POL will focus on the needs of the energy sector for the development of effective tools for better integration of climate change knowledge into policy and planning. The POL is structured around three broad activities; EC participates in all three:

- The potential impacts of climate change on energy production.
- The potential impacts of climate change on energy transmission and distribution.
- The potential impacts of climate change on energy demand.

POL 6.1.1 is scheduled to span 2000–2001 to 2003–2004. Average total funding per year for this POL is $7.3348M. The proposed average PERD funding per year was $2.182M for fiscal years 2000–2004. PERD funds were divided amongst the departments involved in this POL (see Table 17). For this POL, the average leverage quotient of total resources to PERD resources was 3.4.

Table 17
Percentage of PERD Funds for POL 6.1.1 Allocated to Each of the Departments

Department	Percentage of Funds (%)			
	2000–2001	2001–2002	2002–2003	2003–2004
DFO	58.2	48.8	46.5	48.7
EC	38.2	40.3	37.3	34.7
NRCan	3.6	9.5	10.3	15.3
POL Evaluation	0	1.4	0.9	1.4
Communication	0	0	5.0	0

Environment Canada Projects for POL 6.1.1

Climate and Energy in the Toronto–Niagara Region: Integration of Science and Policy

Project Manager: Heather Auld

Overview

The current project builds upon PERD project *Climate and Energy in the Toronto–Niagara Region: Integration of Science and Policy* (two phases), which provided a preliminary integrated assessment of science and policy for climate and energy in the Toronto-Niagara Region (TNR). It also incorporates initial modelling work, which has been supported under PERD through the above mentioned project for 2000–2001. Phase I (1999–2000) provided a partial assessment of the impacts of, and adaptation strategies to, current climate variability and potential climate change on the energy sector (i.e., generation, transmission, and demand). This included a preliminary assessment of their adaptive capacity to recent experiences with climate, vis-à-vis climate change. Phase II (2000–2001) provided a partial assessment of key emission issues facing the energy sector, including implications of changes in the regulatory environment, abatement options, and the potential co-benefits for environment and health from GHG plus related emission reductions (e.g., SO_X, NO_X, PM, VOCs, and HAPs). The proposed work (Phases III and IV) aims to extend this research, addressing key knowledge gaps identified by energy stakeholders in Phases I and II.

Many aspects of past and current PERD deliverables are augmented/complemented by other projects. For example:

- EC–Ontario Region, the City of Toronto, University of Delaware and Kent State University are involved in a United Nations Showcase project that will use synoptic mapping techniques to predict heat wave episodes associated with elevated mortalities in the City of Toronto. The Toronto Heat–Health Alert/Warning project will be piloted this summer. EC will assist the City of Toronto in undertaking adaptation actions to reduce mortalities during heat waves.

- Results from an ongoing Canada–US International Joint Council study on lake level fluctuations and climate change impacts will also be merged with this project.

- The Environmental Engineering Program, University of Regina (Saskatchewan), will be developing the energy model.

- The work on the co-benefits will build on previous Government of Canada multi-departmental studies. The Global Air Issues Branch and the Policy and Communications Branch of EC will provide further consultation if needed.

Objectives

Working with stakeholders in the Toronto–Niagara Region of south-central Ontario, this project will focus on an assessment of the impacts of climate, vulnerabilities to climate, and adaptive strategies to deal with the risks and opportunities associated with climate change conditions. There are six related sub-objectives of the proposed work:

- to assess the vulnerability of the energy sector (production, transmission, and demand) in the Toronto–Niagara Region to climate variability and extreme weather;

- to assess the impacts of climate change on the energy fuel cycle (generation, transmission, and demand) in the Toronto–Niagara Region, in consultation with stakeholders;
- to create regional climate change scenarios for the Toronto–Niagara Region;
- to assess changes (driven by emissions policies) in the energy sector;
- to assess the relative abatement costs and ancillary benefits of GHG plus related emission reductions in the energy sector for the Toronto–Niagara Region; and
- to communicate scientific and technical information on the climate–energy relationship to regional stakeholders and policy makers, and engage them in formulating a plan for a sustainable energy system in the Toronto–Niagara Region.

EC will benefit in many areas from the results of the work. The PERD project will allow EC to investigate alternate approaches (through synoptic map typing) to projecting climate change impacts at the regional scale. It will, for example:

- provide insights into the means for handling return periods or expected recurrence times for the most extreme "extreme events" (e.g., Ice Storm '98);
- work on energy co-benefits and provide further information to address other aspects of EC's air quality/environmental health programs, including information on appropriate regulation limits;
- target towards many facets of the Energy Priority Framework, such as promoting a sustainable energy system from an integrated air issues perspective; involving stakeholders in energy decisions and policy formulation; ensuring the competitiveness of the domestic energy sector in a restructuring environment; and in response to the Kyoto Protocol, helping Canadians to reduce their greenhouse gas emissions 6% below 1990 levels by the year 2010.

Outputs and Methodology

- Assessment of the costs of impacts from current climate on hydro, transmission, and demand (will be guided by stakeholders).
- Assessment of the costs of abatement measures and their potential environment and health benefits (stakeholder community to provide some guidance; peer review to indicate success of benefits assessments).
- Development of statistical synoptic (weather mapping) approaches to determine vulnerabilities or future risks of severe ice and wind storm events under climate warming. (Statistical measures will indicate the success of the synoptic mapping techniques in identifying weather patterns associated with extreme weather events. Meteorological experience will also be used to review performance of identified patterns).
- Assessment of the various approaches for developing regional climate change scenarios.
- Assessment of the impact of climate change scenarios on energy fuel cycle. (Stakeholder consultations will prove invaluable in assessing quality of final results).

Final report. (Stakeholders will receive the final report and will be asked for comments).

The work will be completed in the following phases or steps:

- *Production of Scenarios on Climate and Energy Demand*: Climate change scenarios for dewpoint or relative humidity, wind speed and radiation will be produced after an assessment of the scientific validity of extending downscaling to these variables. The validity will be assessed through reviewing the literature and discussions with personnel at the Climate Change Impacts Scenario Project in Regina. A weather generator will be assessed for generation of daily scenarios of maximum, minimum, and average temperature associated with different climate change scenarios.

Analyses of variability of energy consumption with temperature will be provided by the participating utilities.

- *Assessment of Vulnerabilities of the Energy Sector to Climate Variability and Change*: Other approaches to downscaling will be considered for estimating risks from severe weather events. The future risks associated with severe ice storms (approaching the magnitude of Ice Storm '98) and large-scale severe thunderstorm wind storms will be assessed using statistical synoptic map typing techniques.

- *Costs of Climate Impacts*: During Phase I, stakeholders identified key impacts including: extreme weather events on the transmission grid; lower transmission and distribution efficiency under high temperatures; reduced energy consumption during warm winters; increased energy consumption during summer peak loads; reduced hydroelectricity generation under low lake level conditions; and, reduced efficiency of coal-fired plants and nuclear generating facilities due to warmer water temperatures.

- *Evaluation of the Fuel Mix under Climate Change*: A mathematical optimization model will be constructed to simulate how changes in climate will affect the fuel mix for the TNR. Various mitigation options will be available to the user, such as reduction of the energy used for lighting, reduction of the urban heat island, increasing density of buildings, etc. The options will be presented as reductions by a specified amount or changes in design that the model will translate into reductions.

- *Costs and Benefits of Mitigation Options*: Options proposed through the national implementation strategy on climate change serve as the base for mitigation options to be addressed. The benefits for environment and health will be estimated both quantitatively and qualitatively, adopting a research methodology used by the Environment and Health Impacts subgroup.

- *Communication of Results*: The final report will incorporate the results from the workshop, and include a plan for a sustainable energy system before distribution to energy stakeholders. Following the anticipated submission for peer reviewed publication of the Phase I results (March 31, 2001) it is expected that at least two subsequent articles will be submitted for peer review publication by 2003. Results from this work could also be incorporated into the next phase of the Canada Country Study.

- *Evaluation and Incorporation of Mitigation and Adaptation Strategies into a Plan for a Sustainable Energy System*: Results from the above tasks will be presented to energy stakeholders in a workshop forum. A "Ulysses"-type process will be adopted to facilitate the communication of the results from the analysis.

Funding
The average resources allocated for this project per fiscal year were $172k (1999–2000; 2000–2001). An average 79.5% of these resources came from PERD funds, the rest came from other sources (A-Base, industry, other). The average leverage quotient of total resources to PERD resources for this project was 2.2.

Profiles by Strategic Intent

Climate Sector

Impacts of Climate Change on the Energy Sector

Climate and Energy in the Toronto–Niagara Region

Profiles by Strategic Intent

Climate Sector

Impacts of Climate Change on the Energy Sector

Canadian Participation in FIREIII/SHEBA

Canadian Participation in FIREIII/SHEBA

Project Manager: George Isaac

Overview

This is a new project; it is carried out as part of US lead FIRE III/SHEBA field project. FIRE III/SHEBA is a multimillion dollar US-led project in which measurements were made above, on, and under the ice pack near a Canadian ice breaker located in the Arctic Ocean north of Barrow, Alaska. A general summary of the field project and the goals of FIRE III have been written by Curry *et al.* (2000). AES (now MSC) concentrated its efforts within FIRE III by flying a NRC Convair 580 out of Inuvik during April 1998 to measure the physical, radiative, and chemical properties of the Arctic atmosphere that influence the characteristics of Arctic Stratus. Canadian participation was a small but important part of the overall project. This participation allows quick access to all the information collected by US scientists, and it enables better parameterizations of the cloud microphysical and optical properties that need to be developed for the Canadian Climate Models, and thus better predictions of climate change.

Substantial progress has already been made. The Canadian data have been delivered to the NASA-Langley archive and many complements have been received about its quality. Papers have been written for special Journal of Geophysical Research (JGR) issues on FIRE and SHEBA. Several journal papers have already been accepted to Geophysical Research Letters, the Journal of Climate, the International Journal of Climate, and the Quarterly Journal of the Royal Meteorological Society. The data set is being actively used by many individuals doing studies on better parameterizations of clouds and aerosols within Climate Models and Weather Forecasting Models. Although much work has been done, integration of the data sets, detailed comparisons with models, and summary papers on the effects of climate change in this area remain to be written.

In the final two years, the Canadian effort will involve completion of the analysis of the Arctic atmospheric data and delivery of the results to the climate modelling community. In particular, the work will stress the analysis of the chemistry and physical data, and its importance related to climate change, climate model development, and model/observation comparisons, and the development of better techniques to use remote sensors (satellite and ground-based) to detect important variables in the Arctic. In addition, this project will fund the maintenance of the Canadian data archive and the provision of data in suitable formats to interested researchers.

Objectives

The overall objectives of this PERD project are: (1) to support Canadian participation in the FIRE III/SHEBA projects; (2) to better understand cloud and climate interactions and climate change in the Arctic/Beaufort Sea area; and (3) to better understand climate change in the Arctic Environment where climate feedback effects and temperature changes are predicted to be the largest, and where little information is presently available. The specific objective is to complete the analysis of the arctic atmospheric data that were collected during FIRE III/SHEBA and to deliver the results to the climate modelling community. The research aims to contribute to improvements to climate models, particularly as they relate to arctic climate processes.

The recent studies showed that Canadian Arctic is becoming much warmer than expected. The results from the present work allow scientists at EC to prepare parameterizations of cloud microphysical parameters and cloud processes that are not known for the Arctic environment. Understanding of cloud processes is strongly related to the heat and energy budget of Arctic environment that GCMs try to simulate. The results from the present work can be used to better understand temperature changes in the Arctic so that decision-makers can be better informed about climate change in this very sensitive area.

Outputs and Methodology
The main successes are indicated by progress in the data analysis, insertion of the data into the NASA Data Archive, and publications in the scientific literature (journals and conferences). Most of the data have already been inserted into the NASA-Langley Data Archive and are being used by scientists around the world. The Canadian group was asked to calibrate equipment used on the boundary layer aircraft so that appropriate error bars could be obtained. Such calibration tests were performed in both the NRC and NASA icing tunnels. Efforts will be made to incorporate the knowledge obtained into the Canadian Climate Model being developed in Victoria. This is a complicated process but scientists have already begun to test the sensitivity of the model to new parameterizations developed for the Arctic Region.

The main purpose of this proposal is a continuation of the data analysis already underway. Immediately after the field project, which ended in May 1998, most of the effort was concentrated on the quality controlling of the data and the placement of this data within the NASA archive. This task was completed by summer 1999. Since July 2000, all Canadian FIRE III data are available to the entire research community.

In the current phase of the work, the results will be used for model applications, including single column models that is first step to better understand cloud processes-climate change interactions.

Funding
The average resources allocated for this project per fiscal year were $8.6M (1999–2000; 2000–2001). An average 2.8% of these resources came from PERD funds, the rest came from other sources (A-Base, other). The average leverage quotient of total resources to PERD resources for this project was 36.1.

Profiles by Strategic Intent

Climate Sector

Impacts of Climate Change on the Energy Sector

Climate Change and Anthropogenic Aerosols

Climate Change and Anthropogenic Aerosols

Project Manager: Sunling Gong

Overview
This is the last year of the five-year PERD project on anthropogenic aerosols. It did not stem from a previous PERD project.

This work was done as a part of the NARCM (Northern Aerosol Regional Climate Model) project. The nature of the NARCM aerosol model development is partnership through university and government collaboration. In addition to the approximately 20 involved scientists (including many graduate students), EC has a group of "associates" representing aerosol and climate research community nationally and internationally.

Objectives
- to further our understanding of how Canadian climate may be affected by anthropogenic aerosols by developing a high resolution climate model in the northern latitudes (>35N) that includes size-distributed aerosols as active constituents.

- to provide suitable parameterizations and algorithms and skilled personnel to eventually incorporate aerosols into the Canadian GCM and MAM.

The benefits for EC include: (1) EC has developed the capacity through the PERD project to better understand anthropogenic aerosols and their impacts on climate. The product of this research—CAM (Canadian Aerosol Module) is being used to study the PM in the air quality fields; and (2) EC has gained expertise that can be used to carry out related researches.

Outputs and Methodology
As part of the NARCM project, this PERD project has resulted in the CAM module that is being used in both climate and air-quality models.

For the whole aerosol cycle research, the global size-distributed budgets for these aerosols are obtained. Global spatial and temporal distributions of sea-salt, sulphate, and black carbon aerosols are produced and compared with observations. The global optical depth contributed from each of these aerosols is being analyzed from the global simulation results. A draft paper has been produced to summarize the results.

The development and refinement of the module in NARCM is continuing with the addition of soil dust emission in NARCM. The model is being tested and verified in two different regions: North Africa and East Asia. A new global black and organic carbon aerosol emission source from five contributions is included in NARCM: (1) tropical forest and savanna fires, (2) agricultural and domestic fires, (3) boreal and temperate wildfires, (4) fossil fuel combustion, and (5) natural sources.

The numerical treatment of the aerosol module in NARCM—CAM has been evaluated with sensitivity analysis. Part of the results will be in the CAM paper and the complete results will be published in a full paper.

Funding
The average resources allocated for this project per fiscal year were $693k (1999–2000; 2000–2001). An average 9.1% of these resources came from PERD funds, the rest came from other sources (A-Base, other). The average leverage quotient of total resources to PERD resources for this project was 11.

Climate Change Impacts on Extremes of Heating, Cooling, and Dehumidification Loads

Project Manager: Philip Jarrett

Overview
This project does not stem from a previous PERD project and is not part of a larger project/program.

Objectives
The objectives of this project are: (1) to estimate the impact of a changing climate on extreme heating, cooling, and dehumidification loads in Canadian buildings and industrial sectors; and (2) to provide information on the impacts to codes and standards agencies so that planning contingencies can be designed to ensure energy systems remain effective and efficient under a changing climate into the next century. The successful implementation of this work will result in greater energy efficiency in buildings and certain commercial and industrial processes (possibly as much as 2–3%). The risk of not meeting loads due to not planning contingencies for a changing climate will decrease.

Outputs and Methodology
The outputs include a technical report and electronic publication providing estimates of the effects of climatic change on extremes of heating and cooling loads (2000–2001).

The outputs will be accomplished through:

- consulting with codes and standards agencies to develop alliances and determine best strategies; investigate the literature and consult with Climate Research Branch scientists for appropriate climatic change scenarios;
- planning and conducting an analysis of extreme events over the past 40 years to check for trends and variability in extreme conditions using the data in the National Digital Climate Archive at AES;
- obtaining climate change scenario information and using literature search and data analyses to obtain links between gross climate parameters (described by the scenarios and their output either annually, monthly, or finer temporal-scale information) and the occurrence of extremes; the relationships established above will be applied to current information about extremes to estimate their occurrence under a changed climate scenario.

Funding
The average resources allocated for this project per fiscal year were $14k (1999–2000; 2000–2001). An average 71.4% of these resources came from PERD funds, the rest came from other sources (A-Base). The average leverage quotient of total resources to PERD resources for this project was 1.4.

Profiles by Strategic Intent

Climate Sector

Impacts of Climate Change on the Energy Sector

Sea Ice Climatology Studies

Sea Ice Climatology Studies

Project Manager: Bruce Ramsay

Overview
This project does not stem from a previous PERD project and is not part of a larger project/program.

Objectives
- to prepare a digital ice climate data base which can be used for climate research,
- to update ice climate atlases for Canada, and
- to investigate trends and cycles in the ice climate and perform preliminary investigations of the relationship between these patterns and those in the atmosphere and ocean.

Compilation of the digital charts data base is an invaluable resource to assist in environmental assessments and climate change studies; it provides visibility to EC by being referenced in several climate research projects. The ice atlases are also an asset for EC because these atlases provide updated ice climatology.

Outputs and Methodology
- Digital ice charts data base (completed).
- Updated ice atlases (soft ice atlases for East Coast, Arctic and Hudson Bay were produced and put on CIS Website in 1999–2000).
- Study and report on optimum ice indices produced in 1999–2000.
- Studies and reports on cycles and trends in Canada's ice climate and relationship to the atmosphere produced in 2000–2001.

ArcInfo GIS was used to analyze and produce climate products for ice atlases as well as several scientific projects.

Note: This project has been completed and has met all of its objectives and deliverables.

Funding
The average resources allocated for this project per fiscal year were $240k (1999–2000; 2000–2001). An average 52.1% of these resources came from PERD funds, the rest came from other sources (A-Base, other). The average leverage quotient of total resources to PERD resources for this project was 1.9.

Water Vapour, Water Cycling, Climate and Water Resources

Project Manager: Ron Stewart

Overview
Previous studies have contributed funding to the study of severe storms over the northern portions of the Mackenzie river basin as well as the southern Beaufort Sea. Such studies also laid the groundwork for examining larger issues such as the atmospheric component of the water cycle over northern regions. This was the focus of the 1999–2001 PERD proposal.

This work contributes to and benefits from the Mackenzie GEWEX Study (MAGS). This is a large research effort involving about 30 researchers from Environment Canada and several universities. This effort is concerned with the water cycle over the Mackenzie River basin and involves atmospheric, land surface, and hydrological scientists. This effort recently received a $4.9M NSERC grant to carry it through till the end of 2005.

Objectives
This project addresses a key component of the water cycle that must be well handled if EC is to credibly address water resource issues. It also addresses the conversion of water vapour to precipitation over a range of conditions. Hydroelectricity generation depends on water availability; thus, the energy industry must pay attention to this issue. This project increases EC's capability to document and simulate the atmospheric component of the water cycle over northern regions.

Outputs and Methodology
Diagnostic and modelling studies have been carried out to realize these objectives:

- Diagnostic studies have been conducted on the Mackenzie River basin using the most up-to-date information on the water cycle. This information has been used to document the water cycle and its variations over several decades. The analysis of this information has pointed out the large variation in magnitude of the atmospheric water cycle that occurs and that feeds back into the climate system.

- Several versions of the Canadian Regional Climate Model (CRCM) have been run (northwestern Canada) and the degree to which this model replicates observed trends has been documented. While progress has been made, there are still considerable difficulties in replicating all interacting components of the water cycle. Work has already been carried out on the treatment of clouds in this model in order to improve the representation of the atmospheric water cycle.

The results of these studies have been continually conveyed to the research community and to management within EC. These results have directly and indirectly been made available to those concerned with the water cycle and water resources over the Mackenzie basin and adjacent regions.

The essence of the work will be done within a larger initiative that is now focusing on the Canadian Prairies as well as the Mackenzie basin.

Funding
The average resources allocated for this project per fiscal year were $212k (1999–2000; 2000–2001). An average 38.7% of these resources came from PERD funds, the rest came from other sources (A-Base, industry, other). The average leverage quotient of total resources to PERD resources for this project was 2.7.

Profiles by Strategic Intent

Climate Sector

Impacts of Climate Change on the Energy Sector

Climate Change and Offshore Design Criteria

Climate Change and Offshore Design Criteria

Project Manager: Val Swail

Overview
This project does not stem from a previous PERD project and contributes to overall research efforts on reducing the uncertainty in wind and wave design criteria, in particular, to the PERD project *Offshore Wind and Wave Design Criteria*.

Objectives
The objectives are: to investigate whether and how the marine climate is changing (e.g., becoming more severe or more variable); to determine the potential impacts on the design and operation of offshore facilities and the likely vulnerability of these facilities to climate change. This research contributes to EC efforts in climate change detection, attribution, and prediction, and supports national and international programs such as CLIVAR, IPCC.

Outputs and Methodology

- 2000–2001—Report and scientific journal article on spatial trend, variability of storm frequency, severity, and resulting wind/wave patterns.
- 2001–2002—Report and presentation to oil industry and regulators on climate trend and variability.
- 2002–2003—Assessment of homogeneity of trends in extreme storms from hindcast and measurement.
- 2004–2005—Non–technical summary report for policy makers on storm trends, their effects on design criteria, and their expected vulnerability to climate change.

Results will be based on complex spatial statistical analysis of wind and wave hindcast results produced under the PERD project *Offshore Wind and Wave Design Criteria*, and from the Canadian General Circulation model control and predictive runs through dynamic and statistical downscaling. Work will concentrate on trends and variability in extreme winds and waves, which drive the design criteria.

Funding
The average resources allocated for this project per fiscal year were $134k (1999–2000; 2000–2001). An average 44% of these resources came from PERD funds, the rest came from other sources (A-Base, other). The average leverage quotient of total resources to PERD resources for this project was 2.3.

Measurement of Aerosol/Cloud Feedback Relationships

Project Manager: Bruce McArthur

Overview
This project does not stem from a previous PERD project. The work associated with this PERD project contributed to fundamental questions that were being asked by the World Climate Research Program through the Baseline Surface Radiation Network. The Canadian commitment to this network was used to obtain A-Base support.

Objectives
The original objective of the project was to associate changes in aerosols and clouds using climatological surface measurements and sounding data from the first 1.5 km of the atmosphere. Anthropogenic changes in aerosol brought about by the burning of fossil fuels alter the type, extent, and frequency of cloud fields. In turn, these cloud fields alter the surface radiation budget. The study intended to carry out measurements and then operate radiative transfer models to determine whether such changes could be established experimentally and if so, the magnitude of the changes.

The following benefits were accrued to EC during the life of the project:

- The measurement aspect of this project was designed to feed data into the NARCM model as a validation point.
- During the project a new means of measuring surface radiation fluxes from a tethered balloon platform was developed.
- The project provided partial funding for the support of the measurement of aerosol optical depths and a means of determining the overall amount of aerosols in the atmosphere.
- The analyses indicate that the present measurement techniques used by EC for monitoring surface emitted and reflected fluxes are inappropriate.
- The background aerosol loading over the south-central prairies is possibly the lowest in all of Canada.
- The data indicate that the cloud climatology of the prairies may have changed over the recent past, which could be the result of anthropogenic aerosols.

Outputs and Methodology

- Development of a payload for the measurement of broadband and spectral solar fluxes and broadband infrared fluxes.
- Successful flights of the developed payload providing information leading to conclusions concerning surface radiation fluxes. Results were presented Summer 2000.
- Dataset submitted to the World Radiation Data Centre, Zurich, Switzerland.
- Data collected that is used to determine changes in cloud affects on the surface radiation budget. Results to be presented Summer 2001.
- The aerosol data collected was used to develop a satellite retrieval correction algorithm to be used by the Canada Centre for Remote Sensing.

The original project was the combining of surface-based measurements of aerosol optical properties, radiation measurements and tethered balloon-borne measurements to provide both an input into and validation for radiative transfer models. The project was an attempt to overcome the need for high-cost aircraft experiments as a means of providing the data necessary for climate model closure experiments. Reductions in overall PERD funding and changes in the direction of PERD during the period of the project forced the re-examination of the original objectives. The final objectives were significantly scaled back to include the quality assurance of surface radiation budget measurements suitable for model validation experiments and the development and deployment of a tethered balloon radiation payload.

The data quality assurance program was based on the criterion set out by the Baseline Surface Radiation Network program. The final data would be archived at the World Radiation Data Centre where an independent validation of the data would be undertaken.

The design and development of the payload package were based on an iterative design and construction method where a proof-of-concept product was first launched near the start of the project and a final payload was completed near the end of the second year of the project. Several flights, evaluated upon the experimental results obtained from each flight, were flown during the final two years. The quality of the results of the flights was determined by comparison with concurrent measurements made from tower-mounted instruments located near the flight locations.

Funding
The average resources allocated for this project per fiscal year were $87k (1999–2000; 2000–2001). An average 48.3% of these resources came from PERD funds, the rest came from other sources (A-Base). The average leverage quotient of total resources to PERD resources for this project was 2.1.

Climate/Sea Ice Process Studies Using Satellite Microwave

Project Manager: Tom Agnew

Overview
This project does not stem from a previous PERD project. Under the re-structuring of PERD, a new project, *Critical Aspects of Changes in Sea Ice Cover on Energy Production*, has been accepted which is marginally related to this project. The new project is co-managed by branches of EC, the Canadian Ice Services and the Climate Research Branch.

The project *Critical Aspects of Changes in Sea Ice Cover on Energy Production* is part of the climate change research and climate change monitoring of Canada and is carried out by Meteorological Service of Canada.

Objectives
The objective is to provide a detailed assessment and interpretation of recent sea ice cover trends over Canadian marine areas of importance to hydrocarbon development and transportation and to provide guidance to the oil and gas industry on the implications of these trends.

The CIS digital ice chart data base is the most authoritative and accurate representation of the Canadian ice climate. This project will lead an effort to exploit this knowledge and information resource. It is essential that other Meteorological Service of Canada expertise in ice climate and modelling, and supercomputing resources also contribute to this effort. Analysis of the digital sea ice chart data base will identify errors and biases. To date, no obvious trends have been found. It is believed that this digital data base represents the most accurate depiction of the Canadian ice climate.

Outputs and Methodology
These results will be communicated through journal publications and conference presentations. The observed trends will be compared with the findings from the modelling part of this proposal. These will be used to assess how sea ice conditions will most likely evolve over the next 5–25 years. In particular, the focus will be ice extent, severity, and season duration.

- Report on trend analysis using the CIS 40-year sea ice chart digital data base—March 2002 (both CCRP and CIS are responsible).
- Preparation of satellite data on a common GIS analysis system—March 2002 (CCRP is responsible).
- Complete analysis for western Arctic and write report on results; data preparation and analysis for eastern Arctic and East Coast regions—March 2003 (both CCRP and CIS are responsible).
- Report on coupled ice-ocean simulations of the past and future climate—September 2003 (CIS is responsible).
- Report on predicted trends in sea ice cover for Canadian waters for the next 5–25 years—March 2004 (both CCRP and CIS are responsible).
- Complete analysis and final report on results concerning satellite data set—March 2004 (both CIS and CCRP are responsible).

Profiles by Strategic Intent

Climate Sector

Impacts of Climate Change on the Energy Sector

Climate/Sea Ice Process Studies Using Satellite Microwave

The work is divided into two activities: (1) analysis of the digitized ice charts for the standard operational areas; and (2) development of a coupled ice-ocean model to be used for simulation of future ice climate. The first activity will compare sea ice trends for various regions of Canada with satellite derived sea ice data from passive microwave obtained from NSIDC. Guidance on sea ice trends will be provided by indicating which regions show trends, whether these trends agree with other atmospheric trends in air temperature or circulation, whether trends agree with trends in oceanographic properties, and whether trends agree or disagree with other research results. The second activity will use a large-scale coupled ice ocean model to simulate detailed regional climates and will resolve important passageways through the Canadian Arctic. This will complement GCM predictions by adding spatial detail to the current typical GCM resolution, which is on the order of 200 to 300 km. Also, this approach is much simpler than using a regional GCM, which are still largely in the research domain.

Funding

The average resources allocated for this project per fiscal year were $95k (1999–2000; 2000–2001). An average 73.7% of these resources came from PERD funds, the rest came from other sources (A-Base). The average leverage quotient of total resources to PERD resources for this project was 1.4.

Climate Change Impacts on Hydrologic Cycles and Extremes, with a Specific Focus on the Hydroelectric Industry in Western Canada

Project Manager: Terry Prowse

Overview
The original PERD 1999 proposal had a four-year duration; however, only 1.5 years were completed before the project was revised and integrated with another to form the new PERD POL project. The original PERD project was initiated with funding in July 1999 and has recently been merged with another study (*Predicting Impacts of Climate Change on the Hydrologic Cycle of Northwest Canada: Reducing the Uncertainties for the Energy Sector* –by Philip Marsh) into the new 2001 PERD POL program.

Some of the objectives (e.g., glacier resources) from this 1999–2000 project were not undertaken because the project was only funded at 27% of the request level. Furthermore, these objectives do not form part of the new 2001 POL PERD program which has been expanded to include effects on the energy sector (oil and gas: Mackenzie Delta and arctic lake/river ice) in Arctic Canada.

Objectives
This project stems from work conducted as part of the EC Northern Rivers Basin Study and the subsequent EC Northern Rivers Ecosystem Initiative. It also has strong links with a CCAF project. This original study had four basic objectives as outline in the 1999 proposal:

- Develop coupled atmospheric-hydrologic models for predicting climate-induced changes to the snow and ice reserves of the western Cordillera.
- Establish an historical data base of, and predict future changes to, the snow and ice water resources that contribute to the hydroelectric power potential within western Canada.
- Assess the effects of such changes to the sustainability and potential future expansion of the hydroelectric industry in western Canada.
- Develop a scientifically based decision framework for the optimization of hydroelectric facilities with the dual goal of maximizing power production under future climate-change conditions and minimizing downstream hydrologic impacts.

This study builds on EC's research into the effects of climate change on hydrology and aquatic ecosystems, a major research project of the National Water Research Institute. By linking with the hydroelectric industry, it also creates unique adaptation strategies whereby the effects of climate change might be reduced on vulnerable riparian ecosystems. EC has gained significant international recognition for this original research.

Outputs and Methodology
As per the original project design, this project had the following major deliverables (by project component):

1. Coupling of atmospheric and hydrologic models for evaluating the effects of changes in alpine snow reserves on hydroelectric capacity in the western Cordillera.
   - Coupled atmospheric hydrologic model for application in Canada's western Cordillera.
   - Projections of future snow-water resources for use by the hydroelectric industry in the western Cordillera.

- Assessment of impacts of changing snow reserves on hydroelectric generating capacity in Western Canada.

2. Climate impacts on glacier water resources for the hydroelectric industry in the western Cordillera.

   - Assessment of historical trends in glacier water resources currently contributing to major hydroelectric production in Western Canada.
   - Projections of future glacier-water resources for use by the hydroelectric industry.
   - Assessment of impacts of changing glacier reserves on hydroelectric generating capacity in Western Canada.

3. Climate impacts on the frequency and severity of ice jam flood events in hydroelectric regulated rivers.

   - Predictions of climate-induced changes to the river ice regime of major rivers affected by hydroelectric regulations in Western Canada.
   - Assessment of changes to the frequency and severity of extreme ice jam floods resulting from predicted changes in the ice regime and in runoff from future snow and glacier resources of the western Cordillera (from related studies 1 and 2).
   - Assessment of the impact of altered ice and flooding regimes on the regulation strategies and power production potential of the hydroelectric industry in Western Canada.

Project 1 was to be achieved through the development of a coupled atmospheric and hydrologic model verified on current flow regimes but altered with input from changing runoff regimes produced by climate projections.

Project 2 was to be achieved by assessing current snow and ice resources and with the use of snow and ice models forecast the changes in resources that would result from various GCM–RCM scenarios for the western Cordillera.

Project 3 was to be achieved through a linking of the results of Projects 1 and 2 (changes in snow/ice runoff and related river flow) with a field verified ice jam flood model.

Funding
The average resources allocated for this project per fiscal year were $155k (1999–2000; 2000–2001). An average 32.3% of these resources came from PERD funds, the rest came from other sources (A-Base, other). The average leverage quotient of total resources to PERD resources for this project was 3.1.

Gulf of St. Lawrence Ice-Ocean-Atmosphere Climate Change, Detection and Impact on the Canadian Energy Sector

Project Manager: Gérald Vigeant

Overview

This is a joint project with Fisheries and Oceans Canada. This work complements the modelling development carried out in the 1990s by regional climate modellers (Université du Québec à Montréal) and regional ocean modellers (Institut Maurice–Lamontagne; University of Alaska, Fairbanks).

This project has three important unique aspects:

- The St. Lawrence is well-confined with respect to other oceanic basins and its climate is dominated by air-sea fluxes and the hydrological cycle.
- It is relatively easy to measure conditions of the Gulf of St. Lawrence compared to other Canadian basins as it is supported by a strong and continuous observing system.
- The scientific issues regarding climate changes and sea ice, northern continental runoff, and the anticipated increases in extreme meteorological events, spur immediate concerns for the Gulf of St. Lawrence and its watershed, and also sparks direct interest in understanding the global climate system.

Objectives

This project is aimed at developing a coupled air-ice-ocean regional numerical model capable of reproducing the high frequency and seasonal changes in the weather, currents, ice, and the heat/salt/nutrient/momentum content and fluxes in the St. Lawrence (Gulf and estuary). This work would help predict the St. Lawrence ice-ocean response to changes in hydrological cycle, global warming, and extreme meteorological events and even more, to predict the impacts of climate change on marine transportation, the large and small hydroelectric industry, the oil industry, and the fishing/coastal industries.

The present proposal aims at:

- adapting the hydroelectric, farming, shipping, mining, coastal, and fishing industries to climate increasing the scientific expertise of the St. Lawrence River, and Gulf system;
- better describing detailed processes of the earth's climate system;
- detecting climate change and the potential effects on the energy sector;
- developing the St. Lawrence environmental observing system and a better understanding of the impacts of climate change on natural resources. This project has strong linkages with other projects that aim to deliver better St. Lawrence environmental observations, predictions, and warnings; and,
- financially supporting new regional climate modelling scientists particularly for the northeastern part of North America.

Outputs and Methodology

Several performance indicators have been used including:

- the quality of the regional modelling tools developed throughout the project;
- the number of scientific publications, articles, and presentations to national and international audiences;
- national and international recognition of the innovative work produced directly by the project; and,
- the increased number of new scientists with better knowledge of regional air-ice-ocean modelling.

Profiles by Strategic Intent

Climate Sector

Impacts of Climate Change on the Energy Sector

Gulf of St. Lawrence Ice-Ocean-Atmosphere Climate Change

It is currently impossible to accurately describe how the St. Lawrence system would respond to climate changes. Little is known of the effects of these responses on our societies and the global climate system due to the lack of data, the complexity and natural variability of the system, and the inability to correctly model these processes. The uncertainties of these effects control the hydroelectric potential, the sustainable development of marine transportation, and fisheries in the St. Lawrence, and are linked to our safety and understanding of ocean-atmosphere processes.

It is proposed to conduct a detailed analysis and computational representation of the processes affected by global warming in the St. Lawrence system and in other northern basins (e.g., Hudson Bay). The volume of ice could be greatly reduced by greenhouse warming in northern regions and especially in eastern Canada. It is not yet known how much ice reduction will occur because oceanic fluxes are controlled by an intricate and unknown function of radiative forcing (temperature, winds, radiation, runoff) and mixing. Also, other important questions remain unanswered, such as how the increased gulf exposure to the atmosphere will affect the ocean climate. Natural and human-induced changes in runoff control the transport and climate of the water column of the St. Lawrence system. The effects of changes in the hydrological cycle and the gulf response on regulations for use of St. Lawrence water (e.g., Great Lakes diversions, under keel clearance, and hydroelectric production) are unclear. Computational regional climate models coupled to historical data and GCM predictions are powerful and competitive tools that can be used to help answer these questions.

Funding
The average resources allocated for this project per fiscal year were $102k (1999–2000; 2000–2001). An average 75.5% of these resources came from PERD funds, the rest came from other sources (A-Base). The average leverage quotient of total resources to PERD resources for this project was 1.4.

Predicting Impacts of Climate Change on the Hydrologic Cycle of Northwest Canada: Reducing the Uncertainties for the Energy Sector

Project Manager: Philip Marsh

Overview
This project is a continuation of a project initiated in 1997, and has recently been merged with another study by Terry Prowse (*Climate Change Impacts on Hydrologic Cycles and Extremes, with a Specific Focus on the Hydroelectric Industry in Western Canada*).

This project is closely linked to, and relies on results from, the Mackenzie GEWEX Study (MAGS), and has strong links to a CCAF project.

Objectives
The 1999 proposal outlined the following three main objectives:

(1) Consider natural variability and determine whether a climate change signal is apparent within the existing record, including temperature, precipitation, stream flow, permafrost, and snow/ice.

(2) Further develop and test a various models for considering climate change effects on the hydrologic system in northern Canada.

(3) Carry out a preliminary assessment of the effects of climate change on the hydrology of northern Canada under various GHG/climate change scenarios.

This study builds upon ongoing EC research on the effect of climate change on hydrology and aquatic ecology, a major research area of the National Water Research Institute and an EC priority area. A unique aspect of this study is that it builds upon an ongoing collaboration between NWRI, the Meteorological Service of Canada, and a number of Canadian Universities in the Mackenzie GEWEX Study (MAGS). MAGS brings together both hydrologists and atmospheric scientists in order to provide the models and data sets necessary to provide a better understanding of past and future changes in climate and the related effects on the hydrologic system.

Outputs and Methodology
This project has had the following major deliverables:

a) *Past changes in climate:*
- assessment of changes in temperature and precipitation
- assessment of changes in dates of river breakup and discharge
- consideration of changes in active layer thickness

b) *Model testing and validation:*
- testing of WATFLOOD for basins in NW Canada
- comparison of GEM model predictions to observations
- testing of ice-dammed lake models
- testing of surface energy balance models for snowmelt and evaporation and comparison to both tower and aircraft flux observations

c) *Preliminary assessment of climate change effects:*
- consideration of the potential impact of climate change on hydrology and aquatic ecology
- the initial proposal noted that this task would be a preliminary assessment only, and that full consideration would be left to a future proposal. Due to less than requested funding, a decision was made to leave this portion of the study until high resolution RCM model runs being carried out in MAGS are available for the study area.

The outputs were achieved through:

- Assessment of past changes in climate and hydrology was to be achieved through an analysis of existing records from operational and research stations (Meteorological Service of Canada weather stations, Water Survey of Canada discharge stations, and National Water Research Institute research basins).

- Model testing and validation was to be achieved through the application of a number of models, including WATFLOOD, SNTHERM, various surface energy balance models for determining rates of snow melt and evaporation, ice-dammed lake models, and the comparison of atmospheric models (GEM) to observations.

- Preliminary testing of climate change impacts was to be achieved by driving the models tested in by GCM data for various climate scenarios. The proposal noted that the initial testing would be very preliminary and that a proposal would later be developed for a full program.

Funding
The average resources allocated for this project per fiscal year were $233k (1999–2000; 2000–2001). An average 12.9% of these resources came from PERD funds, the rest came from other sources (A-Base, other). The average leverage quotient of total resources to PERD resources for this project was 7.8.

Strategic Intent 6 · Strategic Direction 2

Strategic Direction 2 is to provide S&T to enhance the natural uptake of GHG's from the atmosphere. More specifically, the program will address:

Strategic Intent 6 · Strategic Direction 2 · Objective 6.2.1

The Development of a Better Understanding of the Relevant Natural GHG Cycles; and Steps to Increase the Net GHG Uptake from the Atmosphere by Forests, Agricultural Lands and Oceans. (Multiplayer)

POL 6.2.1
Past PERD programs and Departmental research activities have contributed to studies on natural processes governing sources and sinks of greenhouse gases within Canada's natural and managed terrestrial ecosystems and adjacent ocean environments. The Enhancement of GHG sinks (EGGS) POL plan seeks to build upon this foundation by undertaking coordinated research efforts directed specifically at those aspects of the science relative to future reporting of sinks under the Kyoto Protocol. Partners in this POL include Agriculture and Agri-Food Canada, EC (POL leader), Fisheries and Oceans Canada, and Natural Resources Canada. The research will complement related GHG cycle research being conducted by government laboratories within these departments, as well as similar activities under the federal CCAF and within the university community (e.g., BIOCAP initiative).

The goal is to develop a better understanding of the role of carbon sinks as feedbacks within the climate system and to ultimately incorporate these feedbacks within climate system models. Types of sinks that will be studied are forests, agricultural soil, oceans, and hydroelectric reservoirs. The main POL activities address three specific areas of research:

- Identifying and understanding the human influences on key processes that govern the fluxes of GHGs within the Canadian forest, agricultural, and ocean ecosystems.
- Develop models to describe the interrelationships between human activities and these processes.
- Using these models, assess the quantity of gases that can be removed from the atmosphere by measures under the Kyoto Protocol and subsequent agreements.

The activities will address four subobjectives, as well as an advisory function, as follows:

Forest sinks:
A better understanding of the impact of human activities on the processes that control the flux of GHGs within, to, and from Canada-managed and unmanaged forest ecosystems, including wetlands and freshwater bodies within their watersheds; the development/assessment of methods for quantifying the net effect of measures taken to enhance the uptake of GHGs within these ecosystems; and improved estimates of the effects of human activities on the storage and release of GHGs in Canada's forest ecosystems; and the communication of such information to policy makers as a scientific basis for the development of GHG sequestration programs.

Agriculatural soil sinks:
A better understanding of the processes that control the flux of GHGs within, to, and from Canada's agricultural ecosystems, development/assessment of methods for accurately quantifying the net effect of measures taken to enhance uptake of GHGs within these systems; and improved estimates of the effect of human activities on their net uptake of GHGs.

Ocean sinks
A better understanding of the processes that control the flux of GHGs within, into, and out of ocean systems adjacent to Canada, and assessing the potential and verifiability of measures to enhance GHG uptake within them (including the environmental risks).

Hydroelectric reservoirs
A better understanding of the processes that affect the fluxes of greenhouse gases into hydroelectric reservoirs, development of methods to accurately quantify changes in net fluxes following hydroelectric developments.

POL 6.2.1 is scheduled to span 2000–2001 to 2004–2005. Average total funding per year for this POL is $6.860M. The proposed average PERD funding per year was $2.223M for fiscal years 2000–2005. PERD funds were divided amongst the departments involved in this POL (see Table 18). For this POL, the average leverage quotient of total resources to PERD resources was 3.1.

Table 18
Percentage of PERD Funds for POL 6.2.1 Allocated to Each of the Departments

Department	Percentage of Funds (%)				
	2000–2001	2001–2002	2002–2003	2003–2004	2004–2005
DFO	33.7	33.3	32.9	30.8	32.0
EC	24.1	25.5	25.0	24.2	25.9
NRCan	22.9	22.9	22.9	26.8	22.9
AAFC	19.2	19.2	19.2	18.3	19.2

Environment Canada Projects for POL 6.2.1

Impact of Variability and Climate Change on Carbon Sequestration in a Boreal Forest

Project Manager: Alan Barr

Overview

This project began as a new PERD project in 1998–1999, and has been extended to 2005 under the current PERD EGGS POL 6.2.1 plan. The research is part of the Boreal Ecosystem Research and Monitoring Sites (BERMS) initiative of the Meteorological Service of Canada (MSC), the Canadian Forest Service, and Prince Albert National Park. The BERMS sites are also flagship sites in the proposed Fluxnet–Canada CO_2 flux network. This work is jointly funded by the MSC, PERD, CCAF and potentially FluxNet Canada (e.g., NSERC funding).

Objectives

- to characterize the seasonal and internal variability in the boreal deciduous forest's carbon and water budgets, by measuring the exchanges of CO_2, water vapour, and energy between the forest and the atmosphere over several complete annual cycles.
- to understand the climatic, hydrologic, and ecophysiological controls on carbon sequestration by boreal deciduous forest.
- to improve the parameterization of boreal deciduous forest in Canadian climate and forest-ecosystem carbon budget models.
- to advise policy makers in the energy sector on the implications of climate change on the future role of the boreal deciduous forest as a carbon sink.

In addition, the BERMS objective (from the 2001–2005 proposal) is to measure and analyze the effect of inter-annual climate variability on the carbon and water balances of deciduous, wet coniferous, and dry coniferous boreal forest ecosystems, and create an integrated, stand-level data base, including carbon, water, and energy fluxes, soil CO_2 efflux, climate, soil moisture, and biophysical data and metadata, for validating process models of the forest carbon balance.

EC's involvement in this project is largely motivated by the needs of the Canadian Land Surface Scheme (CLASS) model, in particular: (1) an improved understanding of the processes that control the carbon and water balances of boreal forest ecosystems; and (2) an integrated, stand-level data base for model development and validation. One tangible benefit to EC will be improved confidence in the performance of the CLASS model for boreal forest ecosystems, leading to improved performance of the Canadian GCM and RCM over boreal forest.

Outputs and Methodology

- Development of an integrated, stand-level data base, and provision of the data base to collaborating modelling groups, leading to a demonstrated improvement in model performance and/or reduced uncertainties in model outputs.
- A report that summarizes the most significant science results from an energy perspective of the climate change and variability theme (PERD EGGS POL 6.2.1) and provides a set of recommendations for policy makers in the energy sector.

The outputs were achieved using:

- Continuous measurement of the exchanges of carbon, water, and energy between deciduous, wet coniferous, and dry coniferous boreal forest stands and the atmosphere, along with supporting climate, soil moisture, and biophysical data, over complete annual cycles.

- Development and provision of an integrated data base of forest ecosystem climate and flux measurements from the BERMS sites to collaborating modeling groups, for developing and validating carbon budget process models.

Funding

The average resources allocated for this project per fiscal year were $255k (1999–2000; 2000–2001). An average 21.6% of these resources came from PERD funds, the rest came from other sources (A-Base). The average leverage quotient of total resources to PERD resources for this project was 4.6.

Science Advisory on Climate Change

Project Manager: Henry Hengeveld

Overview
This project is part of a coordinating function to ensure effective delivery of POL 6.2.1 outputs and a mechanism for advising policy makers of scientific research results as needed for national and international negotiations and policy development with respect to greenhouse gas fluxes and climate change.

Objectives
The overall objectives of the project are to:

- develop and regularly make available to the government specialized information on global warming caused by increasing concentration of greenhouse gases, particularly CO_2; and,
- advise as required on related implications for energy supply and demand in Canada.

Outputs and Methodology
In addressing the above objectives, the following results were achieved during 1996–1997:

- completed comprehensive review of approximately 500 reports and articles which appeared in the 1995 scientific literature;
- publication of a synthesis of 1994 and 1995 literature, complete with bibliographic listing of approximately 880 papers, in a major review report;
- convened and organized a biannual workshop on Canadian research on sources and sinks of greenhouse gases, and published a workshop report;
- prepared three papers for presentation at workshops/conferences and publication in conference proceedings; and
- coordinated the preparation of a national research strategy on climate change and extreme events numerous briefings, seminars, and interviews on global warming, including presentations to senior managers and researchers within NRCan.

Funding:
For fiscal years 1999–2000 and 2000–2001, resources allocated to this project per fiscal year were $108k. PERD funding was not available.

Profiles by Strategic Intent

Climate Sector

Steps to Increase the Net GHG Uptake

Terrestrial CO_2 Sources and Sinks

Estimation of Terrestrial CO_2 Sources and Sinks in Canada

Project Manager: Kaz Higuchi

Overview

This project was a re-focused followup study which employed a coupled three-dimensional regional atmospheric circulation/ecosystem model developed in a previous project. Three years ago, a decision was taken to employ, modify, and improve the three-dimensional model to investigate Canadian boreal forest ecosystems in their role as net carbon sources and sinks. The project allowed the interpretative capability of the model to be used to obtain an estimate of the temporal variation in the strength of the terrestrial CO_2 source and sinks around Fraserdale, in northern Ontario. This was accomplished by using the comprehensive surface and tower CO_2 data obtained at the Fraserdale site under the PERD Project *Atmospheric Greenhouse Gases in the James Bay Region* which ended in the 1997–1998 fiscal year.

Objective

The objective of this project was to perform surface and aircraft measurements at and near Fraserdale, to obtain data to constrain already available models and improve their parameterization of biospheric/atmospheric CO_2 exchange processes. The improved models were then used to interpret the existing six years of CO_2 concentration data from Fraserdale in terms of estimated strength of net biospheric carbon flux in boreal forest ecosystems around Fraserdale. Because of the importance of the policy implication within the Kyoto context, the objective was consistent with the PERD strategic objectives under the Greenhouse Gas Cycle and Storage thrust of the Climate Change Task. The project clearly related to the disposal of excess CO_2 produced by the energy sector, and to climate change, through obtaining better estimates of where anthropogenic CO_2 was being sequestered in the mid-latitude biosphere.

The scientific knowledge gained from this project benefits EC by providing a well-informed basis for its role as the leading department in presenting the Canadian position in the implementation of the terms of the Kyoto Protocol to reduce greenhouse gas emissions. The carbon role of the terrestrial biosphere figures as a very significant component in the terms and fulfillment of the protocol.

Outputs and Methodology

During the three-year life of the project, a total of six intensive field measurement campaigns were successfully carried out at the Fraserdale site: one in 1998, three in 1999, and two in 2000. Each campaign, lasting on average about five days, included surface continuous and flask samplings of CO_2 concentration and isotopes, as well as aircraft measurements of CO_2, isotopes, and meteorological variables. The research also coupled a new ecosystem model, BEPS [from the Canadian Centre for Remote Sensing (CCRS)], to the three-dimensional regional meteorological model, MC2. The coupled model has been used to simulate observations obtained from the field campaigns as a function of spatially and temporally distributed CO_2 sources and sinks in a region around Fraserdale.

The Project was an integrated research strategy in which existing six years of Fraserdale CO_2 data were interpreted by modelling to obtain an estimate of net CO_2 flux in boreal forest ecosystems around Fraserdale. Additional surface and aircraft measurements at and near Fraserdale were obtained to constrain the models, as well as to improve the parameterizations of the biospheric/atmospheric CO_2 exchange processes. The inner grid of MC2 was implemented over a 250 x 250 km region over Fraserdale and was coupled to BEPS at MSC, with collaboration from CCRS. Modelling and data analyses of surface CO_2 concentration, along with relevant meteorological variables such as wind, temperature, and humidity, were performed at MSC. A continuous LICOR measuring system for CO_2 was flown in an aircraft along with a flask sampling system. Flask samples from the aircraft and the surface were analyzed for CO_2 concentration and isotopes at MSC. Some preliminary results were presented at conferences (e.g., The Role of Boreal Forests and Forestry in the Global Carbon Budget Conference) as well as in scientific papers.

Funding

The average resources allocated for this project per fiscal year were $332k (1999–2000; 2000–2001). An average 38.3% of these resources came from PERD funds, the rest came from other sources (A-Base, industry). The average leverage quotient of total resources to PERD resources for this project was 2.6.

Profiles by Strategic Intent

Climate Sector

Steps to Increase the Net GHG Uptake

Terrestrial CO_2 Sources and Sinks

POL Objective Leaders

ANNEX 1 POL OBJECTIVE LEADERS FROM ALL PARTICIPATING DEPARTMENTS

POL Objective Leaders

POL Number	POL Title	POL Leader	E–Mail Address
1.2.1	Offshore Environmental Factors for Regulatory, Design, Safety, and Economic Purposes	Peter Smith	smithpc@mar.dfo-mpo.gc.ca
1.2.3	Marine Transportation and Safety	Robert Frederking	robert.frederking@nrc.ca
1.3.1	Flaring Research Initiative (FRI)	Bill Reynen	bill.reynen@ec.gc.ca
1.3.3	Groundwater and Soil Remediation for the Oil and Gas Industry	Natalie Shea	natalie.shea@ec.gc.ca
2.1.1	Support the Development of Technological and Other Measures to Control and Reduce Emissions of Particulate Matter	Keith Puckett	keith.puckett@ec.gc.ca
2.1.2	Advanced Fuels and Transportation Emissions Reduction	Greg Smallwood	Greg.Smallwood@nrc.ca
2.2.2	Fuel Cells, Electric and Hybrid Vehicles	Martin Hammerli	hammerli@nrcan.gc.ca
2.2.4	Optimization of the Energy Efficiency of Transportation Systems	Michael Ball	ballma@tc.gc.ca
3.2.1	Community Energy Systems	Chris Snoek	csnoek@nrcan.gc.ca
3.2.3	Energy Systems for Sustainable Community Development	Claude Lefrançois	claude.lefrancois@ec.gc.ca
4.3.3	Research, Development, and Deployment for Industrial Separation and Refrigeration (SEPREF)	Jean Paquette	jpaquett@nrcan.gc.ca
4.3.5	The Development of Low Energy Intensity Bioprocessing Techniques	Terry McIntrye	terry.mcintyre@ec.gc.ca
5.1.1	Improving the Economics and Efficiency of Conversion of Renewable Energy to Electricity Including Related Storage, Hybrid, and Systems Technologies	Claude Barraud	cbarraud@nrcan.gc.ca
5.2.1	Characterization of Canadian Fuels and their Emissions (COFE)	Dave Hughes	dhughes@nrcan.gc.ca
5.2.2	Clean and Efficient Combustion Technologies for Large Utility Electricity Generation	Mike Burke	mburke@nrcan.gc.ca
5.2.3	The Capture, Treatment, Transport, Use and Storage of CO_2 from Large Point Sources	Mark Douglas	madougla@nrcan.gc.ca
6.1.1	Climate Change Impacts on the Energy Sector (CCIES)	Allyn Clarke	clarkea@dfo-mpo.gc.ca
6.2.1	Enhancement of Greenhouse Gas Sinks (EGGS)	Henry Hengeveld	henry.hengeveld@ec.gc.ca

Recent Presentations, Conferences, and Publications

Objective 1.2.1

Coupled Atmosphere-Ocean Wave Models

Ice Modelling

ANNEX 2: RECENT PRESENTATIONS, CONFERENCES AND PUBLICATIONS

Strategic Intent 1· Strategic Direction 2· Objective 1.2.1

Offshore environmental factors for regulatory, design, safety, and economic purposes.

Project: ***Data Assimilation into Coupled-Atmosphere-Ocean Models.***

Recent Publications:

Bidlot, J. R., D. J. Holmes, P. A. Wittman, R. Lalbeharry, and H. S. Chen, 2001, Intercomparison of the performance of operational ocean wave forecasting systems against buoy data, Submitted to Weather and Forecasting.

Desjardins, S., J. Mailhot, and R. Lalbeharry, 2000, Examination of the impact of a coupled atmospheric and ocean wave system, Part I: Atmospheric aspects, *J. Phys. Oceanogr., 30*:385–401.

Lalbeharry, R., 2001, Evaluation of the CMC regional wave forecasting system against buoy data, Submitted to *Ocean-Atmosphere*, August, 2001.

Lalbeharry, R., J. Mailhot, S. Desjardins, and L. Wilson, 2000, Examination of the impact of a coupled atmospheric and ocean wave system, Part II: Ocean wave aspects. *J. Phys. Oceanogr., 30*:402–415.

Conference Presentations:

Lalbeharry, R. and W. K. Luo, 2000, Wind wave forecasting on the Great Lakes, Reykjavik, Iceland, 26–29 June.

Lalbeharry, R. and W. K. Luo, 2001, SWAN vs. WAM in shallow water mode on Lake Erie: Some preliminary results. WISE Meeting, Geneva Park, Orillia, Ontario, Canada, 29 April–3 May.

Lalbeharry, R., 2000, A validation study of CMC ocean wave forecasting system, *34th CMOS Congress*, Victoria, BC, Canada, 29 May–2 June.

Lalbeharry, R., 2000, Data assimilation into a coupled atmosphere-ocean wave model system, PERD Workshop, St. John's, Newfoundland, Canada, 25–26 September.

Conference Papers and Technical Memoranda:

Bidlot, J. R., D. J. Holmes, P. A. Wittman, R. Lalbeharry, and H. S. Chen, 2000, Intercomparison of the performance of operational ocean wave forecasting systems against buoy data, *ECMWF Technical Memorandum 315*, Shinfield Park, Reading, U.K., September.

Lalbeharry, R., 2000, Evaluation of the CMC regional wind and wave forecasting system during a 3-year period, *6th International Workshop on Wave Hindcasting and Forecasting*, Monterey, California, U.S.A., 6-10 November.

Luo, W. K. and R. Lalbeharry, 2000, Wind wave forecasting on the Great Lakes. *6th International Workshop on Wave Hindcasting and Forecasting*, Monterey, California, U.S.A., 6–10 November.

Wilson, L.J. and E. Dunlap, 1999, On the use of synthetic aperture radar data for the assimilation of ocean wave spectra, *The Wind-Driven Air-Sea Interface: Electromagnetic and Acoustic Sensing, Wave Dynamics and Turbulent Fluxes,* School of Mathematics, University of New South Wales, Sydney, Australia, M. Banner, ed, pp. 423–430.

Project: ***Operational Ice Modelling***

Recent Publications:

Carrieres, Tom: Operational Ice Model Verification at the Canadian Ice Service, *Annals of Glaciology, 31*:333–338. August 1999.

Crocker, Greg, Collection of Iceberg Model Verification Data, Contractor report from Ballicater Consulting. September 2000.

Savage, Stuart, Analyses for Iceberg Drift and Deterioration Code Development, Technical Report 99–03. November 1999.

Savage, Stuart, Analyses for Evolution of Sea Ice Thickness Distributions, Technical Report 2000–04, September 2000.

Savage, Stuart, Data Assimilation–Ice Sheet Speed-up & Relaxation Times. Technical Report 2000–01, March 2000.

Savage, Stuart, Numerical Integration Scheme for Iceberg Drift and Deterioration Code, Technical Report 2000–02, March 2000.

Savage, Stuart, State of the Art Review – Prediction of Iceberg Deterioration and Drift, Technical Report 99–01, January 1999.

Sayed, Mohamed, Implementation of Iceberg Drift and Deterioration Model, Canadian Hydraulics Centre (NRC) Technical Report HYD-TR-049, March 2000.

Yao, T., C. L. Tang, T. Carrieres, and D. H. Tran: Verification of a Coupled Ice Ocean Forecasting System for the Newfoundland Shelf, *Atmosphere-Ocean, 38 (4):* 557–575. December 2000.

Recent Presentations:

Carrieres, Tom, Operational Prediction of Sea Ice and Icebergs. Presentation to combined workshop of the PERD Ice Coordination Committee, Ice Structure Interaction Committee and Wind and Waves Committee, St John's September 2000.

Carrieres, Tom and Hai Tran, Seasonal simulations with a particle-in-cell sea ice model v 0.5, Poster presentation at *EGS 25th General Assembly*, April 2000.

Recent Presentations, Conferences, and Publications

Objective 1.2.1

Detection of Icebergs

Validation of Wind and Wave Measurements

Offshore Wind and Wave Design Criteria

Carrieres, Tom and Hai Tran, Ice Data Assimilation in a Coupled Ice–Ocean Model, Poster presentation at *AGU Fall Meeting*, December 1999.

Project: *Operational Detection of Icebergs from Remotely–Sensed Data*

C-CORE, 2000, Summary Data Report—Validation of Iceberg Detection Capabilities of RADARSAT Synthetic Aperture Radar. C-CORE Contract Report, KM149-0-85-013, August 2000.

C-CORE, 2000, A technical note on qualitative image analysis for the development of algorithm for the discrimination of icebergs from ships in RADARSAT images, *C-CORE Technical Note*, Issue 1.0, September 11, 2000.

C-CORE, 2000, Preliminary Validation Results - Validation of Iceberg Detection Capabilities of RADARSAT Synthetic Aperture Radar. C-CORE Contract Report, KM149-0-85-013, November 2000.

C-CORE, 2001. Validation of Iceberg Detection Capabilities of RADARSAT Synthetic Aperture Radar – Final Report. C-CORE Contract Report 01-C5 for Canadian Ice Service, February 2001.

Desmond Power, James Youden, Kelley Lane, Charles Randell, and Dean Flett, 2001, Iceberg Detection Capabilities of RADARSAT Synthetic Aperture Radar, submitted to *Canadian Journal of Remote Sensing*.

Flett, Dean, James Youden, Stephanie Davis, Charles Randell, and Matthew Arkett ,2000, Detection and discrimination of icebergs and vessels using radarsat synthetic aperture radar, paper and presentation for *Ship Detection in Coastal Water Workshop*, Digby, Nova Scotia, May 30–June 3, 2000.

Project: *Validation of Buoy and Platform Wind and Wave Measurements*

Blaseckie. M., S. Skey, K. Berger-North, V.R. Swail, and R. McLaren, 1999, The Storm Wind Studies: an investigation into the data recovered from a 6m moored NOMAD buoy on Canada's east and west coasts, *Proc. Data Buoy Cooperation Panel Technical Workshop,* Wellington, N.Z., October 26–27, 1999. DBCP Tech. Doc. 17, pp. 79-89.

Dobson, F.W. and E. Dunlap, 1999, MIROS system evaluation during Storm Wind Study II. *Proc. WMO Workshop on Advances in Marine Climatology* (CLIMAR99), 8–15 September 1999, Vancouver, B.C., pp. 98–109.

Dobson, F.W., R.J. Anderson, P.K. Taylor, and M.J. Yelland, 1999, Storm Wind Study II: Open ocean wind and sea state measurements, *Air Sea Interface Symposium*, Sydney, Australia, January 11–15, 1999.

Dunlap, E., 1999, Air-sea interaction data analysis for the Storm Wind Study II Experiment, *Technical Report ASA 9810*, ASA Consulting Ltd., Halifax, N.S.

Dunlap, E., 2000, Statistical analysis of Storm Wind Study (SWS-2) wind and wave measurements. Contract Report EMD9903P. Prepared for Meteorological Service of Canada, Downsview, Ontario, 17 pp.

Skey, S.G.P., K. Berger-North, V.R. Swail, and A. Cornett, 1999, The Storm Wind Studies (SWS), *Proc. WMO Workshop on Adances in Marine Climatology* (CLIMAR99), 8-15 September 1999, Vancouver, B.C., pp. 59–68.

Taylor, P.K., M.J. Yelland, F.W. Dobson, and R.J. Anderson, 1999, Storm Wind Study II: Wind stress estimates from buoy and ship, *Air Sea Interface Symposium*, Sydney, Australia, January 11–15, 1999.

Project: *Offshore Wind and Wave Design Criteria*

Recent Publications:

Berek, E.P., V.J.Cardone, and V.R. Swail, 2000, Comparison of Hindcast Results and Extreme Value Estimates for Wave Conditions in the Hibernia Area, *Proceedings 6th International Workshop on Wave Hindcasting and Forecasting*, Monterey, CA, 6-10 November 2000.

Cardone, V.J., A.T. Cox and V.R. Swail, 2000, Global Deep Water Wave Climate Specification: Is This Our Final Answer?, *Proceedings 6th International Workshop on Wave Hindcasting and Forecasting*, Monterey, CA, 6-10 November 2000.

Cardone, V.J., A.T. Cox, and V.R. Swail, 2001, Evaluation of NCEP reanalysis surface marine wind fields for ocean wave hindcasts. WMO Guide to the Applications of Marine Climatology, Part II, *World Meteorological Organization*, Geneva, Switzerland.

Cox, A.T. and V.R. Swail, 2001, A global wave hindcast over the period 1958-1997: Validation and climate assessment, *J. Geophys. Res. (Oceans), 106*(C2):2313-2329.

Cox, A.T., V.J. Cardone, and V.R. Swail, 2001, On the use of in situ and satellite wave measurements for evaluation of wave hindcasts. WMO Guide to the Applications of Marine Climatology, Part II.*World Meteorological Organization*. Geneva, Switzerland.

Swail, V. R., A. T. Cox, and V. J. Cardone, 2001, Analysis of wave climate trends and variability. WMO Guide to the Applications of Marine Climatology, Part II.*World Meteorological Organization,* Geneva, Switzerland.

Swail, V.R. and A.T. Cox, 2000, On the use of NCEP/NCAR reanalysis surface marine wind fields for a long term North Atlantic wave hindcast, *J. Atmos. Ocean. Technol. (17):* 532–545.

Swail, V.R., A.T. Cox, and V.J. Cardone, 1999, Trends and potential biases in NCEP-driven ocean wave hindcasts, *Proc. 2nd International Conference on Reanalyses*, 23–27 August 1999, Reading, UK.

Swail, V.R., E.A. Ceccacci, and A.T. Cox, 2000, The AES40 North Atlantic Wave Reanalysis: Validation and Climate Assessment. *Proceedings 6th International Workshop on Wave Hindcasting and Forecasting,* Monterey, CA, 6–10 November 2000

Taylor, P.K., E.C. Kent, M.J. Yelland and B.I. Moat, 1999, The accuracy of marine surface winds from ships and buoys, *Proc. WMO Workshop on Advances in Marine Climatology* (CLIMAR99), 8–15 September 1999, Vancouver, B.C., p. 59–68.

Thomas, B. and V.R. Swail, 1999, A methodology for homogenizing winds from ships and buoys, *Proc. WMO Workshop on Advances in Marine Climatology* (CLIMAR99), 8–15 September 1999, Vancouver, B.C., p. 174–188.

Wang, X.L. and V.R. Swail, 2001, Changes of extreme wave heights in Northern Hemisphere oceans and related atmospheric circulation regimes, *J. Climate* (*in press*).

Wang, X.L. and V.R. Swail, 2002, Trends of Atlantic wave extremes as simulated in a 40-year wave hindcast using kinematically reanalyzed wind fields, Submitted to *J. Climate*.

Presentations:
Presentation of project status, results to international Oil and Gas Producers (OGP) Metocean Committee, Houston, TX, April 7, 2000.

Presentation of project status, results to PERD Offshore Environmental Factors POL Workshop, St. John's, Nfld, September 25–26, 2000.

Presentation of project status, results to international Oil and Gas Producers (OGP) Metocean Committee, Paris, France, October 6, 2000.

Strategic Intent 1 ·Strategic Direction 2 ·Objective 1.2.3

Regulatory requirements for the safe and efficient transportation of oil and gas by tankers and for other occupational and public safety standards.

Project: *Prediction of Small Glacial Mass Distributions*

Recent Publications:
Crocker, Greg, Collection of Iceberg Model Verification Data, Contractor report from Ballicater Consulting, September 2000.

Crocker, Greg, Summary Report Of PERD-CIS Iceberg Modelling Workshop, St. John's, November 1999.

Savage, S., G.B. Crocker, M. Sayed, and T. Carrieres, Size Distributions of Small Ice Pieces Calved From Icebergs, *Cold Regions Science and Technology, (31)*:2 (2000) 163-172. July 2000.

Savage, Stuart, Analyses for Iceberg Drift and Deterioration Code Development, Technical Report 99-03, November 1999.

Savage, Stuart, Bergy Bit and Growler Population Analyses, Technical Report 99-02, June 1999.

Savage, Stuart, State of the Art Review–Prediction of Iceberg Deterioration and Drift, Technical Report 99-01, January 1999.

Sayed, Mohamed, Implementation of Iceberg Drift and Deterioration Model, Canadian Hydraulics Centre (NRC) Technical Report HYD-TR-049, March 2000.

Recent presentations:
Carrieres, Tom, Operational Prediction of Sea Ice and Icebergs, Presentation to combined workshop of the PERD Ice Coordination Committee, Ice Structure Interaction Committee and Wind and Waves Committee. St John's September 2000.

Carrieres, Tom, PERD-CIS Iceberg Modelling Workshop St. John's, November 1999.

Strategic Intent 1 ·Strategic Direction 3 ·Objective 1.3.1

The regulation and reduction of GHG and other atmospheric emissions, primarily from flaring

Project: *Standards for Testing and Certification of Environmentally Efficient*

Recent Publications:
Bourguignon, E., M.R. Johnson and L.W. Kostiuk, The Use of a Closed-Loop Wind Tunnel for Measuring the Efficiency of Flames in Cross-flow, *Combustion and Flame,* 119:319–334 (1999).

Johnson, M.R., J.L. Spangelo, and L.W. Kostiuk, A Characterization of Solution Gas Flaring in Alberta, submitted to the Journal of the Air and Waste Management Association, February 2001, 24 pp.

Johnson, M.R. and L.W. Kostiuk, Efficiencies of Low Momentum Jet Diffusion Flames in Crosswinds, *Combustion and Flame, 123:*189-200,2000.

Kostiuk, L.W., A.J. Majeski, P. Poudenx, M.R. Johnson, and D.J. Wilson, Scaling of Wake-Stabilized Jet Diffusion Flames in a Transverse Air Stream, accepted for publication at the *Twenty-Eighth International Symposium on Combustion*, The Combustion Institute, March 31, 2000.

Conference Papers with Proceedings:
Johnson, M.R. and L.W. Kostiuk, Effects of a Fuel Diluent on the Efficiency of a Jet Diffusion Flame in a Crosswind, presented at *The Combustion Institute, Canadian Section, 1999 Spring Technical Meeting,* Edmonton, Alberta, May 16–19, 1999, 6 pp.

Johnson, M.R., P. Poudenx, D.J. Wilson and L.W. Kostiuk, Evidence for a Fuel Stripping Mechanism in Low-Momentum Jet Diffusion Flames in a Crosswind, presented at the *Combustion Institute, Canadian Section, 2000 Spring Technical Meeting*, Ottawa, Ontario, May 15–17, 2000, Paper #10, 6 pp.

Johnson, M.R., O. Zastavniuk, J.D. Dale, and L.W. Kostiuk, The Combustion Efficiency of Jet Diffusion Flames in Cross-flow, presented at the *Joint Meeting of the United States Sections–The Combustion Institute,* Washington, D.C., March 15–17, 1999, 4 pp.

Recent Presentations, Conferences, and Publications

Objective 1.2.1

Offshore Wind and Wave Design Criteria

Objective 1.2.3

Prediction of Small Glacial Mass Distributions

Objective 1.3.1

Standards for Testing and Certification

Recent Presentations, Conferences, and Publications

Objective 1.3.1

Standards for Testing and Certification

Objective 1.3.3

Wetlands—Containment

Johnson, M.R., O. Zastavniuk, D.J. Wilson, and L.W. Kostiuk, Efficiency Measurements of Flares in a Cross-flow, presented at *Combustion Canada 1999*, Calgary Alberta, May 26–28,1999, 9 pp.

Kostiuk, L.W., M.R. Johnson, and R.A. Prybysh, Recent Research on the Emission from Continuous Flares, presented at *Recent Advances in the Science and Management of Air Toxics, Canadian Prairie and Northern Section (CPANS) and Pacific Northwest International Section (PNWIS) of the Air and Waste Management Association (A&WMA)*, Banff, Alberta, Canada, April 9–12, 2000.

Majeski, A.J., D.J. Wilson, and Kostiuk, Measuring and Predicting the Length of a Propane Jet Diffusion Flame, presented at the *Combustion Institute, Canadian Section, 2000 Spring Technical Meeting,* Ottawa, Ontario, May 15–17, 2000, Paper #7, 6 pp.

Majeski, A.J., D.J. Wilson, and L.W. Kostiuk, Local Maximum Flame Length of Flares in a Crosswind, presented at *The Combustion Institute, Canadian Section, 1999 Spring Technical Meeting*, Edmonton, Alberta, May 16–19, 1999, 5 pp.

Majeski, A.J., D.J. Wilson, and L.W. Kostiuk, Size and Trajectory of a Flare in a Cross-flow, presented at *Combustion Canada 1999*, Calgary Alberta, May 26–28, 1999, 12 pp.

Poudenx, P. and L.W. Kostiuk, An investigation of the Mean Plume Structures of a Flare in a Crosswind, presented at *The Combustion Institute, Canadian Section, 1999 Spring Technical Meeting*, Edmonton, Alberta, May 16–19, 1999, 12 pp.

Poudenx, P., M. Johnson, L. Kostiuk, D.J. Wilson, Local Combustion Efficiency Measurements of Gas Flares, presented at the *Combustion Institute, Canadian Section, 2000 Spring Technical Meeting*, Ottawa, Ontario, May 15–17, 2000, Paper #11, 6 pp.

Prybysh, R.A., M. D. Checkel, and L.W. Kostiuk, Collection and Analysis of Solid-Phase Emissions from Continuous Flares, presented at the *Combustion Institute, Canadian Section, 2000 Spring Technical Meeting*, Ottawa, Ontario, May 15–17, 2000, Paper #21, 5 pp.

Technical Reports:
Kostiuk, L.W. and M.R. Johnson, University of Alberta Flare Research Project Interim Report November 1996–June 2000, University of Alberta, December 2000, p. xxii, 149, (1.5 Mb file).

Majeski, A.J., Size and Shape of Low Momentum Jet Diffusion Flames in Cross Flow, M.Sc. Thesis, Department of Mechanical Engineering, University of Alberta, September 27, 2000, 126 pp.

Poudenx, P., Plume Sampling of Flares in a Crosswind: Structure and Combustion Efficiency, M.Sc. Thesis, Department of Mechanical Engineering, University of Alberta, September 29, 2000, 173 pp.

Invited Presentations:
Johnson, M.R., Flaring, Do We Have A Problem?, invited presentation to Victoria Composite High School Science 30 Class, Edmonton, Alberta, April 7, 1999.

Johnson, M.R., Continuous Gas Flaring -- Efficiency and Emissions, invited lecture to *The Canadian Society for Mechanical Engineering – Edmonton Section*, February 23, 2000.

Johnson, M.R., Sour Gas Well Flaring, invited lecture to the *Edmonton Chemistry Teachers Regional Workshop*, Edmonton, Alberta, May 12, 2000.

Kostiuk, L.W. and M. R. Johnson, Flaring Research Project, presented at *the Environmental Science and Technology Alliance Canada Technology Day*, Toronto, Ontario, November 9, 1999.

Kostiuk, L.W., Flaring: Do We Have a Problem?, keynote address to *The Combustion Institute, Canadian Section, 1999 Spring Technical Meeting*, Edmonton, Alberta, May 16, 19, 1999.

Kostiuk, L.W., Flaring: Do We Have a Problem?, lecture to the *Canadian Society for Mechanical Engineering— Edmonton Section* February 24, 1999

Strategic Intent 1 ·Strategic Direction 3 ·Objective 1.3.3

The remediation of groundwater and soil issues.

Project: *Wetlands–Containment, Transformation and Remediation of Toxic Organics from Natural Gas Condensates and Process Chemicals.*

Recent Publications:
Donahue, R., S.L. Barbour, and J.V. Headley,1999, Diffusion of benzene in Regina Clay. *Canadian Geotechnical Journal*, *36(3)*:430–442.

Headley, J. V., K. M. Peru and L. C. Dickson, 1999, Ion exchange ESI/LC/MS and ESI/LC/MS/MS of alkanolamines in wetland vegetation exposed to sour-gas contaminated groundwater. *Rapid Commun. Mass Spectrom.,13*:730–736.

Headley, J.V., K.M. Peru, and L.C. Dickson, 1999, Gas chromatographic-mass spectrometric determination of sulfolane in wetland vegetation exposed to sour-gas contaminated groundwater. *Journal of Chromatography A, 859*:69-75.

Headley, J.V., B. J. Moore, W. Staudt, S. D. Ross., R.R. Dupont and R.R. Ryan, 1999, A 1998 Investigation of hydrocarbon attenuation in natural wetlands. *Canadian Association of Petroleum Producers Report*, K1-4545, March 1999, 70 pp.

Headley, J.V., Y. Gong, S. Lee Barbour and Ron Thring. 2000, An evaluation of the ideality of benzene, toluene, ethylbenzene, and xylene on activity coefficients in gas condensate and the implications for dissolution in groundwater. *Canadian Water Resources Journal, (1)*:67-79.

Recent presentations:
Headley, J. V., L. C. Dickson, and K. M. Peru. Comparison of levels of sulfolane and diisopropanolamine in wetland vegetation exposed to sour-gas contaminated groundwater, Poster presentation at the *20th Annual Meeting of the Society of Environmental Toxicology and Chemistry (SETAC)* in Philadelphia, Nov. 14–18, 1999.

Headley, J.V and K.M. Peru, 1998, Quantification of alkanolamines in wetland vegetation using ion exchange/ESI/MS with MS/MS confirmation. *PTAC/CAPP Forum*, Calgary, Alberta, January 18, 1999.

Conference Proceedings:
Headley, J.V., K.M. Peru, and L.C. Dickson, 1999, Gas chromatographic-mass spectrometric determination of sulfolane in wetland vegetation exposed to sour-gas contaminated groundwater, *Proceedings of the Amer. Soc. Mass Spectrom.* Dallas, Texas, June 13–17, 1999.

Headley, J.V., K.M. Peru, and L.C. Dickson, 1999, Gas chromatographic-mass spectrometric determination of sulfolane in wetland vegetation exposed to sour-gas contaminated groundwater, *Proceedings of the Amer. Soc. Mass Spectrom.* Dallas, Texas, June 13–17, 1999, 2pp.

Headley, J.V., K.M Peru and L.C. Dickson. Determination of Diisopropanolamine and Sulfolane in Wetland Vegetation, *Proceedings of Western Canada Trace Organics Workshop*, April 28–30, 1999, Calgary, Alberta. 7 pp.

Project: *Pollution Prevention and Control Technologies in the Oil and Gas Industry*

CAPP, 1999, 1998 Summary Report and 1998 Workplan: Strachan Constructed Wetland Pilot Project. Unpublished Report prepared for Canadian Association of Petroleum Producers and Gulf Canada Resources Ltd. File 2334-29-7.

Fedorak, P.M., *et al.* 2000, Role of Microbial Processes on Sulfate-Enriched Tailings Deposits–Final Report prepared for Environment Canada, University of Alberta.

Recent Presentations:
2001 Environmental Research and Technology Development (R&D) Forum for the Upstream Oil and Gas Industry, February 1, 2001 presentations in Calgary, Alberta.

Project: *Biological Barriers in Fractured Bedrock.*

Recent Publications:
Lapcevic P. A., K.S. Novakowski, and E.A. Sudicky, 1999, The interpretation of a tracer experiment conducted in a single fracture under conditions of natural groundwater flow, *Water Resources Research, 35(8):*2301-2312.

Ross, N. 1999, Stimulation d'une microflore des eaux souterraines: évaluation de l'innocuité environnementale dans une perspective de biocolmatage d'un milieu géologique fracturé. Département des génies civil, géologique et des mines. Montréal, École Polytechnique de Montréal, Université de Montréal: 274.

Ross, N., R. Villemur, L. Deschênes, and R. Samson 2001, Clogging of a limestone fracture by stimulating groundwater microbes. *Water Research* (In Press).

Ross, N., R. Villemur, É. Marcandella and L. Deschênes 2001, Assessment of changes in biodiversity when a community of ultramicrobacteria isolated from groundwater is stimulated to form a biofilm, *Microbial Ecology* (In Press).

Recent Presentations:
Ross, N., P. Lapcevic, S. Lesage, K. Novakowski, L. Deschênes, and R. Samson, 2001, Biobarriers in Fractured Rock: Concept Development and Development and Experimental Design. *Fractured Rock 2001*, March 26–28, Toronto, Canada.

Project: Simultaneous Recovery of Inorganic Contaminants and Hydrocarbons from Soils Using Chelation/Solvent Extraction

Recent Presentations:
Presentations and publication of this work include a technical paper presentation entitled "Novel Technology for Simultaneous Removal of Mixed Contaminants from Solid Waste", presented by co-author Monique Punt at the *Seventeenth Technical Seminar on Chemical Spills,* June 12th, 2000 in Vancouver, B.C. The Proceedings of that Seminar include the published paper.

Monique Punt, A further presentation of the project was also made at the most recent PERD progress report forum

Project: *Standardization and Validation of Terrestrial Toxicity Test Procedures for Assessing Biological Effects in Hydrocarbon Contaminated Soils*

Recent Publications:
Stephenson, G.L., N. Koper, G.F. Atkinson, K.R. Solomon, and R.P. Scroggins, 2000, Use of nonlinear regression techniques for describing concentration-response relationships of plant species exposed to contaminated site soils, *Environ. Toxicol. Chem., 19*: 2968–2981.

Stephenson, G.L., N.C. Feisthauer, and J. Princz, 2000, Assessment of the biological test methods for terrestrial plants and soil invertebrates: Metals. Prepared for Method Development and Applications Section, Environmental Technology Centre, Environment Canada, Ottawa, ON. 40 p. (Appendices).

Annex 2

Recent Presentations, Conferences, and Publications

Objective 1.3.3

Assessment of Phytoremediation

Project: ***Assessment of Phytoremediation as an In-Situ Technique for Cleaning Oil Contaminated Sites***
Literature review to assess the success of current phytoremediation techniques for reclaiming hydricarbon contaminated soils and groundwater, and disposal of contaminated biomass.

PhytoPet CD - searchable database of candidate plant species with demonstrated ability or potential for tolerance to petroleum hydrocarbons and their capacity to reduce hydrocarbons levels in terrestrial and wetland environments.

Strategic Intent 2 ·Strategic Direction 1 ·Objective 2.1.1

Support for the development of technological and other measures to control and reduce emissions of particulate matter.

Objective 2.1.1

Airborne Carbonaceous Particles

Characterization of Particulates—Transportation Fuels

Project: ***Determination of the Concentration, Composition and Sources of Airborne Carbonaceous Particles in Canada***

Recent Presentations:
A CD-ROM of recent presentations and publications prepared May 2001.

Project: ***Characterization of Particulates—Transportation Fuels***

Recent Publications:
Noseworthy ,L., Evaluation of the EPA PART5 Model in Light of Recent Emissions Measurements, ERMD Report #00-53.

Graham, L., Gaseous and Particulate Matter Emissions from In–use Light Duty Motor Vehicles, ERMD Report #99-67.

Welburn, C. and L. Graham, On–Road Motorcycle Emissions—Characterization of Particulate Matter and Gaseous Emissions, ERMD Report #99-68.

Particulate Matter from Mobile Sources—Considerations for Sample Collection Methodologies, ERMD Report # 98-02

Recent Presentations:
Graham, L. and L. Noseworthy, Gaseous and Particulate Matter Emissions from 70 In–Use Light Duty Vehicles in the Lower Fraser Valley, presented at the *11th CRC On-Road Vehicle Emissions Workshop*, 26–28 March, 2001.

Karman, D., C. Welburn, and L. Graham, Mass Emission Rates and Chemical Characterization of PM2.5 emissions from two Motorcycles, presented at the *11th CRC On–Road Vehicle Emissions Workshop*, 26–28 March, 2001.

Strategic Intent 2 ·Strategic Direction 1 ·Objective 2.1.2

The design and use of gaseous and liquid hydrocarbon fuels and associated technologies to achieve emissions reductions.

Objective 2.1.2

Environmental Properties of Diesel Ethers

Project: ***Environmental Properties of Diesel Ethers.***

No publications available at this time.

Impact of Alternative and Reformulated Fuels

Project: ***Environmental Impact of the Use of Alternative and/or New Reformulated Fuels and Development of Advanced Engine/Vehicle Technologies for Use in Light- and Heavy-duty Motor Vehicles.***

Recent Publications: The report prepared by Pacific Vehicle Testing Technologies Ltd. comparing emissions trends of bi-fuel, mono-fuel and gasoline vehicles in the Lower Fraser Valley using data collected over the past eight years is to be published.

Strategic Intent 2 ·Strategic Direction 2 ·Objective 2.2.2 The development of fuel cell, electric and hybrid vehicle components and their supporting infrastructures.

Objective 2.2.2

Fuel Cell Vehicle Life Cycle Emissions

Project: ***Fuel Cell Vehicle Life Cycle Emissions and Environmental Assessment***

Recent Publications: The University of Manitoba has completed a report exploring the potential for using fuel cells in railway locomotives to improve energy efficiency and reduce emissions from locomotive systems. The report provides some very useful comment on the state of fuel cell progress in general, and some insight into current thoughts in railway traction technology. To be published in the near future.

Strategic Intent 2 ·Strategic Direction 2 ·Objective 2.2.4

The optimization of the energy efficiency of transportation systems.

Project: ***The St Lawrence Routing Management Support Model***

Recent Publications:
N. Michaud, Presentation at the commanding officers workshop, December 2000.

R. Corriveau, Presentation at Shipping Federation of Canada, December 2000.

N. Michaud, Presentation at Canadian Coast Guard Marine Advisory Council, Laurentian region», October 2000.

N. Michaud, Presentation at Groupe Desgagnés shipping Inc and St Lawrence Shipowners Association, June 2000

Comfort G., B. Paterson, Y. Gong, L. Luznik., Route forecasting studies for the Gulf of St Lawrence: pack ice measurement and analysis of ship transit data. March 2000.

Enfotech Technical Services, Improving Methodologies for Vessel Routing in the St Lawrence System: Cost/Benefit Analysis Final report, March 2000.

N. Michaud, Presentation at Shipping Federation of Canada, December 1999

N. Michaud, Presentation at the commanding officers workshop, November 1999.

N. Michaud, Presentation at Canadian Coast Guard Marine Advisory Council, Laurentian region, October 1999.

N. Michaud, Presentation at Oceanex Shipping Inc., September 1999.

Comfort, G., Y. Gong, S. Singh, Investigation of pack ice pressure in the Gulf of St Lawrence, March 1999.

Saucier, F. J., J. Stronach, J. Wang, and M. Besner. 1999, Hindcast of high-frequency to inter-annual ice-ocean conditions in the Estuary and Gulf of St. Lawrence, Canadian Meteorological and Oceanographic Society, Montreal.

Roy, F., P. Pellerin, F.-J. Saucier, and H. Ritchie, 1999, Coupled ice-ocean-atmosphere forecast in the Gulf of St. Lawrence, Canadian Meteorological and Oceanographic Society, Montreal

Strategic Intent 3 ·Strategic Direction 2 ·Objective 3.2.1

The establishment of cost-effective interconnections of heat sources and sinks at the community level, which promote the use of energy appropriate to its quality.

Project: ***Advanced Tools and Procedures for Implementing Thermal Energy Storage in Large Institutional Buildings, Commercial Buildings and Community Oriented Applications***

Recent Publications:
Cruickshanks, F., The Earth for Storing Energy. Green Lane, Environment Canada. December 1999.

Research/Internal Reports:
Pre-feasibility for the Amherst ATES Project-A collaboration with the Amherst Hospital Board, William Nycum and Associates (Architects) *et al.* A report to the Amherst Hospital Board (1999).

Refereed Conference Proceedings (Published or in Press):
Cruickshanks, F. Environmental Assessment Guide for UTES Applications-Results from IEA-ECES Annex 8. *Terrastock 2000, 8th International Conference on Thermal Energy Storage*, Stuttgart, Germany, August 2000.

Cruickshanks, F. *In situ* Measurement of Thermal Properties in a Bore-hole in Meguma Slate, Halifax, Nova Scotia: Preliminary Data. *Terrastock 2000, 8th International Conference on Thermal Energy Storage*, Stuttgart, Germany, August 2000.

Non-Refereed Conference Papers and Presentations:
Allan, D. and F.Cruickshanks, April 2000, Assessment off the Potential for Low Temperature Geothermal Energy and Aquifer Themal Energy Storage (ATES) Systems in the Western Canadian Sedimentary Basin. An Overview and Update, Environment Canada, April 2000. IEA-ECES Annex 13, Edmonton, Alberta, April 2000.

Cruickshanks, F. and D.Stewart Underground Thermal Energy Storage in Thermal Solar Applications. Rise and Shine 2000. *The 26th Annual Conference of the Solar Energy Society of Canada Inc. and Solar Nova Scotia*. October 2000 Halifax, Nova Scotia.

Cruickshanks, F. and H. Williams, April 2001, *In-Situ* Evaluation of a Concentric Bore-hole Heat Exchanger for Improved Thermal Energy Transfer.

Cruickshanks, F., Overview of IEA-ECES Energy Storage R&D. Program. *Fourteenth International AWEA - CanWEA, Wind-Diesel Workshop,* September, 2000. Charlottetown, Prince Edward Island, Canada.

Cruickshanks, F., Underground Thermal Energy Storage-Utilization and Benefits, *Atlantic Coastal Action Plan Annual Conference*, Miramichi, New Brunswick (Fall 2000).

Gale, J., R. MacLeod, F.Cruickshanks, and H. Williams, Fracture Stimulation and Related Well Yield in Newfoundland, *IEA-ECES Annex 13*. Edmonton, Alberta, April, 2000.

Recent Presentations, Conferences, and Publications

Objective 2.2.4

St. Lawrence Routing Management Support Model

Objective 3.2.1

Thermal Energy Storage in Large Buildings

Recent Presentations, Conferences, and Publications

Objective 3.2.1

Thermal Energy Storage in Large Buildings

Other Evidence of Impact and Contributions:
Organizer of Symposia, workshops and Meetings: *International Energy Association – Energy Conservation through Energy Storage Implementing Agreement (IEA-ECES).*

Annex 13, Design, Construction and Maintenance of UTES Wells and Bore-holes, Edmonton, Alberta, April 2000.

Annex 14, cooling in All Climates with Thermal energy Storage, Dartmouth N.S., April 2000.

Collaborative Projects:
Development of a Bore Hole Thermal Response Test Apparatus in collaboration with the University of Lulea (Sweden) and Fox Technologies (Halifax, N.S).
Formal PERD Collaboration with NRCan and PWGSC, Cost Effective Community Energy Systems.

ATES Water Treatment Technologies, University of Stuttgart, Germany and Nova Scotia Agricultural College, Truro, Nova Scotia.

Sussex Hospital ATES Pilot Project

Sussex Hospital Hybrid Snow Storage for Cooling Project

Objective 4.3.3

Microwave Assisted Processes

Strategic Intent 4 · Strategic Direction 3 · Objective 4.3.3

The development of advanced technologies and products for heat management and separation including high efficiency drying.

Project: *Applications of Microwave-Assisted Process (MAP) to Solvent-Less Synthesis and to Low Solvent, Energy-Efficient Extraction (11307)*

Paré, J. R. J., U. S. Patents 5,675,909; 5,732,476; 5,884,417, and 6,061,926.

Recent Publications (since 1999 only):
Alfaro M. J, F. C. Padilla, J. M. R. Bélanger, and J. R. J. Paré, Evaluation and Validation of a New Microwave-Assisted Process Technology: Gas-Phase Extraction for Plant Products (*in preparation*).

Alfaro M. J., F. C. Padilla, J. M. R. Bélanger, and J. R. J. Paré, Optimization of a Liquid-Phase Microwave-Assisted Process Extraction of Ginger (Zingiber officinale) (*in preparation*).

Dai, J., V. A. Yaylayan, J. R. J. Paré, and G. S. V. Raghavan, Extraction and Colorimetric Determination of Azadirachtin Related Limonoids in Neem Seed Kernel, *J. Agric. Food Chem.*, 47:3738–3742 (1999).

Dai, J., V. A. Yaylayan, G. S. V. Raghavan, J. R. J. Paré, Z. Liu, and J. M. R. Bélanger, Influence of Operating Parameters on the Use of the Microwave-Assisted Process (MAP) for the Extraction of Azadirachtin Related Limonoids from Neem (*Azadirachta indica*) under Atmospheric Pressure Conditions, *J. Agric. Food. Chem.*, *49:*4584-4588 (2001).

El Khouri Sandra, J. R. J. Paré, and J. M. R. Bélanger, Extraction of Fat from various Cacao samples using MAP™ (in preparation).

Garcia J. A., J. R. J. Paré, and J. M. R. Bélanger, The Microwave-Assisted Process (MAP™): Applications to the Extraction of Palm Oil, *PALMAS, 21(2):*371–384 (2000).

Hong N., V. A. Yaylayan*, J. R. J. Paré, and G. S. V. Raghavan, Microwave-Assisted Extraction of Phenolic Compounds from Grape Seed, *Natural Products Letters, 15:*197-204 (2001).

Irama Alvarez, J. R. J. Paré, and J. M. R. Bélanger, A study of curry powder using MAP Head Space .

Jankowski K., G. LeClair, J. M. R. Bélanger, and J. R. J. Paré, Microwave-Assisted Diels-Alder Synthesis.

Jankowski K., G. LeClair, J. M. R. Bélanger, J. R. J. Paré, and M.-R. Van Calsteren, Microwave-Assisted Diels-Alder Synthesis, Can. *J. Chem., 79:*1906-1909 (2001).

Kwon J.-H., J. M. R Bélanger, and J. R. J. Paré, Prediction of Microwave-Assisted Extraction Conditions for Ginseng Components by response Surface Methodology (*in preparation*).

Kwon J.-H., J. M. R. Bélanger, and J. R. J. Paré, A Possible Extraction of Pesticide Residues in Plant Matrices Using Microwave-Assisted Process (*in preparation*).

Kwon J.-H., J. M. R. Bélanger, J. R. J. Paré, and V. A. Yaylayan, A New Application of the Microwave-Assisted Process (MAP™) to the Fast Extraction of Ginseng Saponins (*in preparation*).

Paré J. R. J. and J. M. R. Bélanger, Operational Parameters in Microwave-Assisted Processes; *En Route* Toward the Control of a "Microwave Effect" (*in preparation*).

Paré, J. R. J., J. M. R. Bélanger, B. Lesnik, R. D. Turpin, and R. Singhvi, Final Evaluation of US EPA Method 3546: A Microwave-Assisted Process (MAP™) Method for the Extraction of Contaminants Under Closed-Vessel Conditions, *Soil & Sediment Contamination, (10):*375–386 (2001).

Punt, M. M., G. S. V. Raghavan, J. M. R. Bélanger, and J. R. J. Paré, Microwave-Assisted Process for the Extraction of Contaminants from Soil, *J. Soil Contamin., (8):*577–592 (1999).

Yaylayan, V. A., J. R. J. Paré, G. Matni, and J. M. R. Bélanger, MAP™: Microwave Assisted Extraction of Fatty Acids and Py/GC/MS Analysis of Selected Insects, *Natural Products Letters, (15):*187–195 (2001).

Yaylayan, V. A., J. R. J. Paré, G. Matni, and J. M. R. Bélanger, Microwave-Assisted Extraction of Cockroaches, *Natural Products Letters*, XX, 000-000 (in print).

Communications (1998–1999 only):
Paré, J.R.J., J.M.R. Bélanger, MAP™: Uses Within Environment Canada, Pacific Environmental Science Centre, Vancouver, BC, February 1999 (invited lecture).

Paré, J.R.J., J.M.R. Bélanger, Industrial Applications of the Microwave-Assisted Processes (MAP™) Technologies, Confidential lecture for a private sector firm, Vancouver, BC, February 1999 (invited lecture).

Paré, J.R.J., J.M.R. Bélanger, M.J. Alfaro, and F.C. Padilla, Liquid- and Gas-Phase Microwave-Assisted Process (MAP™) Extraction of Ginger (Zingiber officinale), *50th Pittsburgh Conference*, Orlando, FL, March 1999 (poster).

Paré, J.R.J., J.M.R. Bélanger, V. Yaylayan, F. van de Voort, and G. Matni, Rapid Determination of Fat From Food Products Using a MAP™ Method, *50th Pittsburgh Conference*, Orlando, FL, March 1999 (poster).

Paré, J.R.J., J.M.R. Bélanger, Vl. Schmitt, and P. Jaquault, Determination of Volatile and Semi-Volatile Organic Compounds Using a Focused Microwave-Assisted Gas-Phase Extraction Process (MAP™), *50th Pittsburgh Conference*, Orlando, FL, March 1999.

Paré, J.R.J., Microwave-Assisted Sample Preparation From a Commercial Laboratory Point of View, Confidential lecture for a private laboratory, Vancouver, BC, March 1999 (invited lecture).

Paré, J.R.J., MAP™: Uses Within Revenue Canada, Laboratory and Scientific Services Directorate, Revenue Canada, Ottawa, ON, April 1999 (invited lecture).

Paré, J.R.J., J.M.R. Bélanger, E. Norrena, D.E. Thornton, and M. M. Punt, MAP™Environment Canada's Contribution to "Green Processing" Technology, *Roadmapping Workshop on Electrotechnology and Alternative Reaction Mechanisms*, Green Chemistry Institute, Houston, TX, October 1998 (upon invitation only).

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Paré, J.R.J., M. Alfaro, J.M.R. Bélanger, and F. Padilla, Optimización de un proceso asistido por microondas (MAP™) en fase liquida: Compuestos volatiles del jengibre (Zingiber officinale), *II Congreso Venezolano de Ciencia y Tecnología de Alimentos,* Caracas, Venezuela, April 1999 (poster).

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Paré, J.R.J., J.M.R. Bélanger, and S. Bourgeau, Microwave-Assisted Processes (MAP™) – A Family of Technologies for Sample Preparation, *Australian International Symposium on Analytical Science*, Melbourne, Australia, July 1999 (invited lecture).

Paré, J.R.J., J.M.R. Bélanger, M. J. Alfaro, and F. C. Padilla, Liquid- and Gas-Phase Microwave-Assisted Process (MAP™) Extraction of Ginger (*Zingiber officinale*), *Australian International Symposium on Analytical Science,* Melbourne, Australia, July 1999 (lecture)

Paré, J.R.J., J.M.R. Bélanger, R. Turle, and S. Bourgeau, Determination of Volatile and Semi-Volatile Organic Compounds Using a Focused Microwave-Assisted Gas-Phase Extraction Process (MAP™), *Australian International Symposium on Analytical Science*, Melbourne, Australia, July 1999 (lecture)

Paré, J.R.J., F.C. Padilla, M. J. Alfaro, and J. M. R. Bélanger, Liquid-Phase Microwave-Assisted Process (MAP™) - Extraction of Cacao, *10th World Congress of Food Science and Technology*, Sydney, Australia, October 1999.

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Paré, J.R.J., Equipment Design Considerations in Manufacturing Microwave-Assisted Headspace Samplers, Shimadzu Corp., Kyoto, Japan, November 1999 (invited lecture).

Paré, J.R.J. and J.M.R. Bélanger, Microwave-Assisted SynthesisA New Tool for the Organic Chemistry Practitioner, National Chung-Hsing University, Taichung, Taiwan February 2000 (invited lecture).

Paré, J.R.J., J.M.R. Bélanger, G. Hatfield, and S. Splinter, Microwave-Assisted Processes (MAP™): Extraction of Canola Oil, *Microwave 2000: Sustainable Technology for the New Millennium and the 3rd Chinese Microwave Chemistry Symposium*, Tianjin, China, May 2000 (invited lecture).

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Recent Presentations, Conferences, and Publications

Objective 4.3.3

Microwave Assisted Processes

Objective 4.3.5

Renewable Energy Production

Objective 5.2.1

Contaminants in Coal

Objective 5.2.2

Pollution from Stationary Combustion Sources

Paré, J.R.J., J.M.R. Bélanger and J.-F. Rochas , Bench-Scale Processing Equipment for Optimising Industrial Applications of the Microwave-Assisted Processes (MAP™), *Microwave 2000: Sustainable Technology for the New Millennium and the 3rd Chinese Microwave Chemistry Symposium*, Tianjin, China, May 2000 (lecture).

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Paré, J.R.J., MAP™: An Environment Canada Commercialization Success Story, *FPTT Workshop*, Ottawa, ON, June 2000 (invited lecture).

Paré, J.R.J. and J.M.R. Bélanger, MAP™: Historical Notes and Perspectives, Business Lecture to NORAM Engineering, Vancouver, BC, August 2000 (invited lecture).

Bélanger, J.M.R. and J.R.J. Paré, Microwave-Assisted Processes MAP™: An Energy Efficient "Green Processing Technology", *International Symposium on Ecomaterials*, Ottawa, ON, Canada, August 2000 (invited lecture).

Paré, J.R.J., J.M.R. Bélanger and D. Bérubé, Improving the Monitoring of Priority Metal Forms via Advanced Speciation, *Toxic Substance Research Initiative Regional Conferences*, Montréal, QC, Canada November 2001 (poster).

Paré, J.R.J., The Microwave-Assisted Processes (MAP™): A Historical Perspective, *COLACRO IX*, Cartagena, Colombia, February 2002 (Invited Keynote Lecture).

Paré, J.R.J., J.F. Rochas, J. Jacomino, F. N. Sánchez L., and J. M.R. Bélanger, A New Tool: The Dielectmeter, *COLACRO IX*, Cartagena, Colombia, February 2002 (poster).

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Paré, J.R.J., J. M. R. Bélanger, M. Siu, and V. A. Yaylayan, Microwave-Assisted Synthesis of Poly(ethyleneglycol) Modified Merrifield Resins, *COLACRO IX*, Cartagena, Colombia, February 2002 (poster).

Paré, J.R.J., V. A. Yaylayan, M. Law, M. Tateyama, and J. M. R. Bélanger, Synthesis and Py-GC/MS Analysis of Polymer-Linked Sugar-Amino Acid Conjugates, *COLACRO IX*, Cartagena, Colombia, February 2002 (poster).

Paré, J.R.J., F. N. Sánchez L., J. M. R. Bélanger, M. J. Alfaro, and F. C. Padilla, Microwave-Assisted Gas-Phase Extraction (MAP-HS) in the Analysis of Volatile Components of Ginger, *COLACRO IX*, Cartagena, Colombia, February 2002 (poster).

Paré, J.R.J., J. M. R. Bélanger, F. N. Sánchez L., J. F. Rochas, and K. Komori, Microwave-Assisted Processes (MAP™)Novel Equipment for the Automation of Gas-Phase Extraction and Analysis, *COLACRO IX*, Cartagena, Colombia, February 2002 (poster).

Paré, J.R.J., Microwaves for Liquid- and Gas-Phase Extraction, Pre-Conference Course, *COLACRO IX*, Cartagena, Colombia, February 2002.

Strategic Intent 4 ·Strategic Direction 3 ·Objective 4.3.5

The development of low energy intensity bioprocessing technologies.

Project: ***Bioprocess Improving Bioenergy Production and Saving Energy.***
Presentations to Simon Fraser Symposium on Biobased Economy (May 4, 2001) *OECD Cleaner Industrial Products and Processes Meeting in Paris* (May 21–23).

Presentation to the Canadian Society of Microbiology/AGM on June 11–14.

Strategic Intent 5 ·Strategic Direction 2 ·Objective 5.2.1

The Characterization of Canadian Fuels and their Emissions (COFE) for more efficient and environmentally benign electricity generation.

Project: ***Environmental Contaminants in Coal and Coal Byproducts.***

Recent Publications:
Goodarzi, F., *Chemical Characteristics of Milled–Coal, Ashes and Stack Emitted Materials from a Western Canadian Coal–Fired Power Plant*, Geological Survey of Canada, Natural Resources Canada, January 2000.

Strategic Intent 5 ·Strategic Direction 2 ·Objective 5.2.2

The conversion of fossil fuels to electricity more efficiently with ultra-low environmental emissions.

Project: ***Prevention, Control and Mitigation of Pollution from Stationary Combustion Sources***

Recent Publications:
Tan, P.V., M.M. Fila, E.J. Evans, Aerosol Laser Ablation Mass Spectrometry of Suspended Powders from PM Sources and its Implications to Receptor Modelling, University of Toronto, submitted to *Journal of the Air & Waste Management Association*, Nov. 2000.

Granatstein, D.L., R.E. Talbot, E.J. Anthony, Application of IGCC Technology in Canada - Phase IV, , CANMET Energy Technology Centre, Natural Resources Canada, March 2001.

Lee, S.W., B. Kan, R. Pomalis, Characterization of Fine Particulates and Investigation of Variables Controlling Particle Formation in Oil and Coal Combustion, CANMET Energy Technology Centre, Natural Resources Canada.

Strategic Intent 5 ·Strategic Direction 2 ·Objective 5.2.3

The capture, treatment, transport, use and storage of CO_2 from large point sources.

Project: Sustainable Development of Coalbed Methane; A Life-Cycle Approach to Production of Fossil Energy

Law D.H.S, W.D. Gunter, S. Wong and M. Mavor, "Sustainable Development of Coalbed Methane: A Life-Cycle Approach to Production of Fossil Energy–Proof of Concept", *Proceedings of 16th World Petroleum Congress*, Calgary, Canada, June 11–15, 2000.

Wong W., W.D. Gunter, and John Gale, Site Ranking for CO_2-Enhanced Coalbed Methane Demonstration Pilots, *Proceedings of the 5th International Conference on GHG Control Technologies*, Cairns, Australia, August 13–16 2000.

Wong, S. and W.D. Gunter, (1999). Testing CO_2 - Enhanced Coalbed Methane Recovery, Greenhouse Issues, IEA Greenhouse Gas R&D Programme, November, Number 45, p. 1–3.

Wong, S., W.D. Gunter, and M.J. Mavor ,2000, Economics of CO_2 Sequestration in Coalbed Methane Reservoirs, *Proceeding of SPE/CERI Gas Technology Symposium 2000*, SPE 59785, April 3–5, Calgary, Alberta, p631–638.

Wong, S., W.D. Gunter, and S.Bachu, Geological Storage for CO_2: Options for Alberta, *Combustion Canada '99 Combustion and Global Climate Change: Canada's Challenges & Solutions*, Calgary 26–28 May, 1999.

Strategic Intent 6 ·Strategic Direction 1 ·Objective 6.1.1

The development of a better understanding of the impacts of climate change on the energy sector, improvement in the forecasting of those impacts and the development of some possible response strategies.

Project: Climate Change and Anthropogenic Aerosols

Recent Publications and In Preparation:
Huang J.P., S.L. Gong , L.A. Barrie , J. -P. Blanchet, and Juan Sebast, Spatial-Temporal Variability of Aerosol Optical Properties Simulated in CAM/GCM III, JGR, 2001.

Zhang, L. S.-L. Gong, J. Padro and L. Barrie, 2001, A Size-segregated Particle Dry Deposition Scheme for an Atmospheric Aerosol Module, *Atmospheric Environment*, 35(3):549–560.

Project: Sea Ice Climatology Studies

Internet:
Soft atlases on CIS Website (March 2000)

Reports:
Documentation for the Canadian Ice Service Digital Sea Ice Database (March 2000).

The Canadian Ice Service Digital Sea Ice Database: Assessment of trends in the Gulf of St. Lawrence and Beaufort Sea Regions, November 2000.

Factors Influencing Ice Climate Trends in the CIS Database (March 2001).

Paper to be presented at POAC 2001 conference.

Project : Water Vapour, Water Cycling, Climate and Water Resources

Recent Publications:
Liu, J., H.-R. Cho, and R.E. Stewart, 2001, Characteristics of water vapor transportation over the Mackenzie River basin during the 1994–1995 water year. *Atmos.-Ocean (special MAGS issue*, Accepted).

Cao, Z., B.P. Proctor, H. Ritchie, M. Wang, R.E. Stewart and G.S. Strong, 2001, Physical processes governing the water budget of and the discharge from the Mackenzie basin for the 1994–1995 water year. *Atmos.-Ocean (special MAGS issue,* Accepted).

Cao, Z., R.E. Stewart, and W. Hogg, 2001, Extreme winter warming events over the Mackenzie basin: dynamic and thermodynamic contributions. *J. Meteor. Soc. Japan* (In Press).

Stewart, R.E., J.E. Burford, and R.W. Crawford, 2000. On the water cycle of the Mackenzie River basin. *Cont. Atmos. Physics, (9):103-110* (special BALTEX issue).

Project: *Climate Change and Offshore Design Criteria*

Recent Publications:
Berek, E.P., V.J.Cardone, and V.R. Swail, 2000, Comparison of Hindcast Results and Extreme Value Estimates for Wave Conditions in the Hibernia Area. *Proceedings 6th International Workshop on Wave Hindcasting and Forecasting*, Monterey, CA, 6-10 November 2000.

Cox, A.T. and V.R. Swail, 2001, A global wave hindcast over the period 1958-1997: validation and climate assessment. *J. Geophys. Res. (Oceans), 106 (C2)*:2313-2329.

Swail, V.R., E.A. Ceccacci, and A.T. Cox, 2000, The AES40 North Atlantic Wave Reanalysis: Validation and Climate Assessment. *Proceedings 6th International Workshop on Wave Hindcasting and Forecasting*, Monterey, CA, 6–10 November 2000

Recent Presentations, Conferences, and Publications

Objective 6.1.1

Climate Change and Offshore Design Criteria

Aerosol/Cloud Feedback Relationships

Impacts on Hydrologic Cycles and Extremes

Swail, V.R. and A.T. Cox, 2000, On the use of NCEP/NCAR reanalysis surface marine wind fields for a long term North Atlantic wave hindcast. *J. Atmos. Ocean. Technol., 17*:532–545.

Swail, V. R., A. T. Cox, and V. J. Cardone, 2001, Analysis of wave climate trends and variability. *WMO Guide to the Applications of Marine Climatology, Part II. World Meteorological Organization.* Geneva, Switzerland.

Wang, X.L. and V.R. Swail, 2001, Changes of extreme wave heights in Northern Hemisphere oceans and related atmospheric circulation regimes, *J. Climate*, in press.

Wang, X.L. and V.R. Swail, 2002, Trends of Atlantic wave extremes as simulated in a 40-year wave hindcast using kinematically reanalyzed wind fields, Submitted to *J. Climate*.

Project: *Measurement of Aerosol/Cloud Feedback Relationships*

Recent Publications:

Bokoye, A.I., A. Royer, N.T. O'Neil, G. Fedosejevs, P.M. Teillet, and B. McArthur, 2001a, Characterization of atmospheric aerosols across Canada from a ground-based sunphotometer network: AEROCAN. *Atmosphere-Ocean*, submitted.

Fedosejevs, G., N.T. O'Neill, A. Royer, P.M. Teillet, A.I. Bokoye, and B. McArthur, 2000, Aerosol optical depth for atmospheric correction of AVHRR composite data. *Canadian Journal of Remote Sensing, 26(4):273–284.*

McArthur, L.J.B. , I. Abboud, D.H. Halliwell, and D.I. Wardle, 2001, Short-term Variation in the Radiation Climate as Monitored at the Bratt's Lake, Canada BSRN Observatory. To be presented at *IAMAS Symposium*, July 10–18, Innsbruck, Austria.

McArthur, L.J.B. and D. H. Halliwell, 2000, Radiation budget measurements in the lower troposphere. *International Radiation Symposium*, 24–29 July, St. Petersburg, Russia.

Project: *Climate Change Impacts on Hydrologic Cycles and Extremes, with a Specific focus on the Hydro-Electric Industry in Western Canada.*

Recent Publications:

Beltaos, S. and T.D. Prowse, 2001, Climate impacts on extreme ice jam events in Canadian rivers. *Hydrological Sciences Journal 46(1):*157–181.

Leconte, R., A. Pietroniro, D.L. Peters, and T.D. Prowse, 2001, Effect of flow regulation and hydroclimatic conditions on the Peace-Athabasca Delta 1996 summer flood. *Regulated Rivers: Research & Management 17*:51–65.

Leconte, R., D.L. Peters, A. Pietroniro, and T.D. Prowse, 1999, Climate fluctuation and the hydrologic response of the Peace-Athabasca Delta, *Abstracts of the 25th Scientific Meeting of the Canadian Geophysical Union*, May 9–13, Banff, Canada.

Peters, D.L and T.D. Prowse, 2001, Regulation effects on the lower Peace River, Canada, *Hydrological Processes* (in press).

Peters, D.L. and T.D. Prowse, 2000, Impact of reservoir operation on Peace River Delta flows, 1986-96, *Elements, 18 (2)*: 6–10.

Peters, D.L. and T.D. Prowse, 2000, Impact of flow regulation on Peace River Delta flows, 1986-96, *Abstracts of the 26th Scientific Meeting of the Canadian Geophysical Union*, May 23–27, Banff, Canada.

Peters, D.L., T.D. Prowse, A. Pietroniro, and R. Leconte, 1999, Episodic flooding of a northern delta ecosystem, *Abstracts of the 25th Scientific Meeting of the Canadian Geophysical Union*, May 9–13, Banff, Canada.

Prowse, T.D., 2001, An adaptation strategy for mitigating the combined d effects of climate variability and flow regulation on a major river delta, *European Geophysical Society, 26th General Assembly, Geophysical Research Abstracts, vol. 3,* 2001.

Prowse, T.D. and S. Beltaos, 2001, Climatic control of river-ice hydrology: a review, *Hydrological Processes* (in press).

Prowse, T.D. and M. Conly, 2001, Multiple-hydrologic stressors of a northern delta ecosystem, *Journal of Aquatic Ecosystem Stress and Recovery 8(1):17*–26.

Prowse, T.D., D. Peters, A. Pietroniro, R. Leconte, A. Chan-McLeod, and J. Toyra, 1999, Flood restoration via a climate shift and flow enhancement, *Abstracts of the 25th Scientific Meeting of the Canadian Geophysical Union*, May 9–13, Banff, Canada.

Romolo, L.A., T.D. Prowse, D. Blair, and L.W. Martz, 2000, The synoptic climate controls on the hydrology of the Peace-Athabasca Delta region, *Abstracts of the 26th Scientific Meeting of the Canadian Geophysical Union*, May 23–27, Banff, Canada.

Töyrä, J., A. Pietroniro, L.W. Martz, and T.D. Prowse, 2000, A multi-sensor approach to wetland flood monitoring, *Hydrological processes* (in press).

Töyrä, J., A. Pietroniro, L.W. Martz, and T.D. Prowse, 2000, Summer flood mapping in a northern wetland using a combination of SPOT and Radarsat imagery, *Abstracts of the 26th Scientific Meeting of the Canadian Geophysical Union,* May 23–27, Banff, Canada.

Töyrä, J., A. Pietroniro, T.D. Prowse, and L.W. Martz, 1999, A multi-sensor approach to wetland monitoring, *Abstracts of the 25th Scientific Meeting of the Canadian Geophysical Union,* May 9–13, Banff, Canada.

Recent Presentations, Conferences, and Publications

Objective 6.1.1

Gulf of St.Lawrence Ice-Ocean-Atmosphere Climate Change

Climate and Energy in the Toronto–Niagara Region

Canadian Participation in FIREIII/SHEBA

Project: ***Gulf of St. Lawrence Ice-Ocean-Atmosphere Climate Change, Detection and Impact on the Canadian Energy Sector.***

Scientific contributions (30+ publications, 50+ scientific presentations, participation to 10+ scientific events, supervision of 3 graduate/post-graduate students) in addition to the coordination of the project and the creation of a highly skilled and trained scientific releve specialized in regional ocean-climate modelling in Canada.

Publications (Partial List):

Besner M. 1999, Méthode pour estimer des variables météorologiques horaires à partir d'observations de navires et de stations terrestres, Rapport scientifique, Environnement Canada- Région du Québec, ISBN 0-662-83785-1, 63 pp.

Bourgault D., F.J. Saucier, and C. Lin, 1999, Shear instabilities in the St. Lawrence Estuary, Canada: a comparison of numerical results and fine-scale observations, *Geophysical research abstracts, EGS, 24th general assembly* 1(2), p. 379, and submitted to *Journal of Geophysical Research.*

Racine D., J. Milton, J., and G. Vigeant, 1999, Le climat et la reconstruction des zones sinistrées, Environnement Canada- Région du Québec, ISBN 0-662-83783-5, 175pp.

Presentations (Partial List):

Gachon P., 1999, Effect of sea-ice distribution on mesoscale cyclone development and regional climate, presented at the *7th Canadian Workshop on Regional Climate Modelling*, Estérel, Québec, May 23–27, 1999.

Gilbert D. 1998, Les courants dans le détroit de Cabot, *66th ACFAS Congress*, Université Laval, Québec.

Lin C., 1999, Modelling the atmospheric flow over the St. Lawrence basin, presented at the *7th Canadian Workshop on Regional climate modelling workshop*, Estérel, Québec, May 23–27, 1999.

Marsh, P., W. Quinton, J. Pomeroy, C. Onclin, N. Neumann, M. Russell, S. Pohl, P. Schuepp, J.

MacPherson, and W. Rouse, 2000, Water cycle processes and modelling at the arctic treeline, Canadian Water Resources Association, June 2000, Saskatoon, Sask.

Marsh, P., W. Quinton, N. Neumann, C. Onclin, S. Pohl, J. Pomeroy, M. Russell, and R. Essery, 2000, Snowcover melt and runoff at the forest-tundra transition zone: Mackenzie River Basin, Research Report of IHAS No. 7. *Proceedings of the GAME-MAGS International Workshop*, Ohata, Nov. 1999, Edmonton, Alberta. Institute for Hydrospheric-Atmospheric Sciences, Nagoya University, Nagoya, Japan.87–91.

Petrone, R. M., W. R. Rouse, and P. Marsh, Comparitive surface energy budgets in western and central subarctic regions of Canada, *The International Journal of Climatology*, in press.

Quinton, W. L., D. M. Gray, and P. Marsh, 2000, Subsurface drainage from hummock-covered hillslopes in the arctic-tundra, *Journal of Hydrology, 237*:113–125.

Project: ***Climate and Energy in the Toronto-Niagara Region: Integration of Science and Policy***

Recent Publications:

Chiotti, Q., A. Basiji, A. Maarouf, and H. Auld, 2000, Climate and Energy in the Toronto-Niagara Region: Report on the Workshop on Climate Variability and Change—Impacts and Adaptation. Forthcoming.

Chiotti, Q. and N. Urquizo, 1999, The Relative Magnitude of the Impacts and Effects of GHG – Related Emission Reductions (Downsview: Environment Canada), 63 pp.

Chiotti, Q., A. Maarouf, and T. Allsopp, 1999, Towards a Renewable Energy Future: Natural Gas and Atmospheric Issues, Toronto: Ontario Natural Gas Association.

Project: ***Predicting Impacts of Climate Change on the Hydrologic Cycle of Northwest Canada: Reducing the Uncertainties for the Energy Sector***

Recent Publications:

Marsh, P. and N. N. Neumann, Submitted, Rapid drainage of ice-rich permafrost dammed lakes in NW Canada. Submitted to the CGU-HS/ESC *Special Issue of Hydrological Processes.*

Marsh, P., C. Onclin, and N. Neumann, 2001, Water and energy fluxes in the lower Mackenzie Valley, 1994–1995. *Atmosphere-Ocean*, Accepted to the MAGS 94/95 water year special issue.

Marsh, P., C. Onclin, N. Neumann, M. Russell, P. Schuepp, and J. I MacPherson, 2000, Spatial variability of surface fluxes during the spring melt period at the arctic treeline, NWT, *Canadian Geophysical Union – HS*, May 2000, Banff, Alberta.

Project: Canadian Participation in FIREIII/SHEBA

Recent Publications:

Bilodeau, B., J. Mailhot, A. Tremblay, A. Glazer, and S. Belair, 1999, Mesoscale Modeling During FIRE-III: 1. Flight Guidance And Model Performance, *Proceedings 5th AMS Polar Meteorology and Oceanography Conference,* Dallas, Texas, 145–149.

Boudala, F.S., G.A. Isaac, Q. Fu, S.G. Cober, and A.V. Korolev, 2000, Sensitivity of radiation models to parameterization of Arctic cloud ice water content versus particle area and length, *Proceedings 13th International Conference on Clouds and Precipitation*, Reno, 600–603.

Curry, J.A., P.V. Hobbs, M.D. King, D.A. Randall, P. Minnis, G.A. Isaac, J.O. Pinto, T. Uttal, A. Bucholtz, D.G. Cripe, H. Gerber, C.W. Fairall, T.J. Garrett, J. Hudson, J.M. Intrieri, C. Jakob, T. Jensen, P. Lawson, D. Marcotte, L. Nguyen, P. Pilewskie, A. Rangno, D. Rogers, K.B. Strawbridge, F.P.J. Valero, A.G. Williams, and D. Wylie, 2000, FIRE Arctic Clouds Experiment, *Bulletin of American Meteorological Society, 81:*5–29

Recent Presentations, Conferences, and Publications

Objective 6.1.1

Canadian Participation in FIREIII/SHEBA

Climate/Sea Ice Process Studies Using Satellite Microwave

Objective 6.2.1

Carbon Sequestration in a Boreal Forest

Glazer, A., A.Tremblay, J.Mailhot, B.Bilodeau, S.Belair, and G. Isaac, 1999, Mesoscale modeling during FIRE.ACE: 2.Modeled arctic clouds and aircraft Observations, *Proceedings 5th AMS Polar Meteorology and Oceanography Conference*, Dallas, Texas, 180–185.

Gultepe, I, G.A. Isaac, and K. Strawbridge, 1999, Comparisons of microphysics and dynamics in arctic clouds during FIRE.ACE: April 8 and 24 case studies, *Proceedings 5th AMS Polar Meteorology and Oceanography Conference*, Dallas, Texas, 174–179.

Gultepe, I., G.A. Isaac, and S.G. Cober, 2000a, Assessing the relationship between ice crystal effective size and temperature, *Proceedings 13th International Conference on Clouds and Precipitation*, Reno, 550-552p.

Gultepe, I., G.A. Isaac, D. Hudak, R. Nissen, and J.W. Strapp, 2000b, Dynamical and microphysical characteristics of Arctic clouds during BASE, *J. of Climate, 13*:1225–1254.

Gultepe, I., G. A. Isaac, and S. G. Cober, 2001, Ice crystal number concentration versus temperature. Accepted to *International J. of Climate.*

Gultepe, I., and G. Isaac, 2001, An analysis of ice crystal number concentration versus aerosol related parameters and supersaturation during FIRE. ACE, *AMS 6th Conference on Polar Meteorology*, San Diego, CA, USA, 14-18 May 2001, 236–239.

Lohmann, U., J. Humble, W.R. Leaitch, G.A. Isaac, and I. Gultepe, 2001, Simulation of ice clouds during FIRE.ACE using the CCCMA single column model. Accepted to *J.G.R.*

Korolev, A.V., G.A. Isaac, and J. Hallett, 1999, Ice particle habits in Arctic clouds, *Geophys. Res. Let., 26*:1299–1302.

Korolev, A., G.A. Isaac, and J. Hallett, 2000, Ice particle habits in stratiform clouds, *Q.J.R.M.S. 126*:2873-2902.

Strapp, J.W., J. Oldenburg, R. Ide, Z. Vukovic, S. Bacic and L. Lilie, 2000, Measurements of the Response of hot-wire LWC and TWC probes to large droplet clouds, *Proceedings of the 13th International Conference on Clouds and Precipitation*, Reno Nevada, August 2000, 181–184.

Twohy, C.H., J.W. Strapp, and J.R. Oldenburg, 2000, Performance of a Counterflow Virtual Impactor at the NASA Icing Research Tunnel, *Proceedings of the 13th International Conference on Clouds and Precipitation*, Reno Nevada, August 2000, 206–209.

Wendisch, M., T. Garrett, P.V. Hobbs, and J.W. Strapp, 2000, PVM- 100A performance tests in the NASA and NRC wind tunnels, *Proceedings of the 13th International Conference on Clouds and Precipitation*, Reno Nevada, August 2000, 194–197.

Project: ***Climate/Sea Process Studies Using Satellite Microwave***

Agnew, T., B. Alt, R. DeAbreu, and S. Jeffers, 2001, The Loss of Decades Old Sea Ice Plugs in the Canadian Arctric Islands, *Polar Met. and Ocean Conference*, AMS, San Diego, May 14–18.

Jeffers, S., T. A. Agnew, B. Taylor Alt, R. De Abreu, and S. McCourt, 2000, Investigating the Anomalous Sea Ice Conditions in the Canadian High Arctic (Queen Elizabeth Islands) During the Summer of 1998, *Annals of Glaciology, IGS Symposium on Sea Ice and Its Interactions with the Ocean , Atmosphere and Biosphere*, June 19–23, 2000, Fairbanks, Alaska in press.

Falkingham, J., R. Chagnon, S. McCourt, 2001, Sea ice in the Canadian Arctic in the 21st Century presented at the *Ports and Ocean Arctic Conference (POAC)*, 2001.

Strategic Intent 6 ·Strategic Direction 2 ·Objective 6.2.1

The development of a better understanding of the relevant natural GHG cycles; and steps to increase the net GHG uptake from the atmosphere by forests, agricultural lands and oceans.

Project: The Impact of Climatic Variability and Change on CarbonSequestration in a Boreal Deciduous Forest

Recent Publications:

Arain, A., T.A.Black, D.L Verseghy, and A.G. Barr, 2001, Carbon balance of boreal deciduous and conifer ecosystems using the Canadian Land Surface Scheme (CLASS), Submitted *to Can. J. Forest Research*, Edmonton 2000 Carbon Conference Special Issue.

Barr, A.G., G. van der Kamp, R. Schmidt, and T. A. Black, 2000, Monitoring the moisture balance of a boreal aspen forest using a deep groundwater piezometer, *Agric. For. Meteorol.,102*:13–24.

Barr, A.G., T.A. Black, X. Lee, T.J. Griffis; R.M. Staebler, J.D. Fuentes, Z. Chen, and K. Morgenstern, 2001, Comparing the carbon balances of boreal and temperate deciduous forest stands. Submitted to *Can. J. Forest Research*, Edmonton 2000 Carbon Conference Special Issue.

Black, T.A., W.J. Chen, A.G. Barr, M.A. Arain, Z. Chen, Z. Nesic, E.H. Hogg, H.H. Neumann, and P.C. Yang, 2000, Increased carbon sequestration by a boreal deciduous forest in years with a warm spring, *Geophys. Res. Lett. 27*: 1271–1274.

Conference Presentations:

Arain, A., T.A. Black, D.L Verseghy and A.G. Barr, 2000, Carbon balance of boreal deciduous and conifer ecosystems using the Canadian Land Surface Scheme (CLASS), *International Science Conference, The Role of Boreal Forests and Forestry in the Global Carbon Budget*, Natural Resources Canada and Canadian Forest Service, Edmonton, May 8–12, p. 16.

Barr, A.G., T.A. Black, X. Lee, R.M. Staebler, J.D. Fuentes, and Z. Chen, 2000, Comparing the carbon balances of mature boreal and temperate deciduous forest stands, *International Science Conference, The Role of Boreal Forests and Forestry in the Global Carbon Budget*, Natural Resources Canada and Canadian Forest Service, Edmonton, May 8–12, p. 98.

Black, T.A., W.J. Chen, A.G. Barr, M.A. Arain, Z. Chen, E.H. Hogg, and Z. Nesic, 2000, Impact of spring temperature on carbon sequestration by a boreal aspen forest, *International Science Conference, The Role of Boreal Forests and Forestry in the Global Carbon Budget*, Natural Resources Canada and Canadian Forest Service, Edmonton, May 8–12, p. 99.

Project: Science Advisory on Climate Change

Recent Publications and Conference Proceedings

Hengeveld, H., 1999, Climate Change and Extreme Weather. To be published in Science of Climate (V. Ramaswamy, ed., La Jolla International School of Physics (peer reviewed).

Hengeveld, H., 2000, Climate control report: The science. *Alternatives Journal, 26 (2):*15–16.

Hengeveld, H. and D. Francis, 2000, Canadian climate models as windows to the future: How credible are they? *CMOS Bulletin, 28:*111-116.

McBean, G.A. and H.G. Hengeveld, 2000, Communicating the science of climate change: a mutual challenge for scientists and educators, *Can. J. Environmental Education 5:*1-19 (peer reviewed).

Milleti, D.S., 1999, *Disasters by Design*, Joseph Henry Press, Washington, D.C., 351 pp. (H. Hengeveld, contributing author).

Reports/Discussion Papers:

Hengeveld, H. 1999, 1997 In Review: An Assessment of New Developments Relevant to the Science of Climate Change. CO_2/Climate Report 99-1, *Environment Canada, and Climate Change Newsletter Vol 11 (2)*, Bureau of Resource Sciences, Australia. 1999.

Hengeveld, H. 2000, 1998 In Review: An Assessment of New Developments Relevant to the Science of Climate Change. CO_2/Climate Report Spring 2000, *Environment Canada, and Climate Change Newsletter Vol 12 (3):*1–52 Bureau of Resource Sciences, Australia. 2000.

Hengeveld, H., 2000, 1999 In Review: An Assessment of New Research Developments Relevant to the Science of Climate Change, CO_2/Climate Report Spring 2001, Environment Canada, and Climate.

Hengeveld, H. and P. Edwards, 2001, CO_2/Climate Report Winter 2001, Environment Canada.

Hengeveld, H.G., 2000, Projections for Canada's Future Climate: A Discussion of Recent Simulations with the Canadian Global Climate Model. *Climate Change Digest* CCD 00-01, 27pp., Environment Canada.

Hengeveld, H.G. and Francis,D., 2000, Canadian climate models as windows to the future: How credible are they? *The Climate Network Spring 2000 (Vol. 5, No 1), and CMOS Bulletin, 28:*111-116.

Oral Presentations (Partial list):

2000

Jan 18.....*McMaster—Hodgins lecture*
Jan 19.....*McMaster—Engineering students*
Feb 3.....*IES graduate course*
Feb 15.....*Toronto environment teachers*
Mar 1.....*Rotary Club North York*
March 22.....*Vancouver Globe 2000*
March 28.....*Queens' student teachers*
April 5.....*Ottawa Rockcliffe*
May 25.....*Stilfecroft school*
May 29.....*Quebec Hydrogen meeting*
June 14.....*Carleton University*
June 21.....*Saskatoon CWRA*
Aug 6..... *ASA meeting, Massachusetts*
Aug.....*York U at Boyne River school*
Oct 2.....*Perth*
Oct 20.....*TDCHS x2*
Nov 12.....*U Western Ontario*
Nov 20.....*Media presentation, the Hague*
Nov 22.....*Media presentation, the Hague*

2001

Jan 25.....*Carbon Sinks Policy Workshop Ottawa*
Jan 29.....*Ottawa Sinks Research Workshop*
Jan 30.....*TDCHS—Woodbridge*
Feb 16.....*Halifax*
Feb 19.....*MSC seminar*
Feb 22.....*Sudbury land reclamation workshop*
Feb 27.....*Toronto Forestry Impacts Workshop*
March 31.....*Environmental journalists*

Project: Estimation of Terrestrial CO_2 Sources and Sinks in Canada

Some preliminary results were presented at *The Role of Boreal Forests and Forestry in the Global Carbon Budget Conference* (Edmonton, Alberta, May 8-12, 2000), and results of a more detailed analyses will be given at the *6th International CO_2 Conference* (Sendai, Japan, Oct 1-5, 2001); scientific papers will be written and submitted to a special issue of *Tellus* dedicated to the presentations at the CO_2 Conference.

ANNEX 3 ENVIRONMENT CANADA PROJECT MANAGERS

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ANNEX 4 LIST OF ENVIRONMENT CANADA'S PERD PROJECTS

POL #	Project Manager	Project Title
POL 1.2.1	Offshore environmental factors for regulatory, design, safety, and economic purposes.	
	Tom Carrières	Operational Ice Modelling
	Dean Flett	Operational Detection of Icebergs from Remotely-Sensed Data
	Val Swail	Validation of Buoy and Platform Wind and Wave Measurements
	Val Swail	Offshore Wind and Wave Design Criteria
	Lawrence Wilson	Data Assimilation into Coupled Atmosphere-Ocean Wave Models
POL 1.2.3	Regulatory requirements for the safe and efficient transportation of oil and gas by tankers and for other occupational and public safety standards	
	Tom Carrières	Prediction of Small Glacial Mass Distributions
POL 1.3.1	The regulation and reduction of GHG and other atmospheric emissions, primarily from flaring.	
	Bill Reynen	Standards for Testing and Certification of Environmentally Efficient Flaring
POL 1.3.3	The remediation of groundwater and soil issues.	
	Richard Scroggins	Standardization and Validation of Terrestrial Toxicity Test Procedures for Assessing Biological Effects in Hydrocarbon Contaminated Soils
	Bill Reynen	Pollution Prevention and Control Technologies in the Oil and Gas Industry
	John Headley	Wetlands - Containment, Transformation and Remediation of Toxic Organics from Natural Gas Condensates and Process Chemicals
	Suzanne Lesage	Biological Barriers in Fractured Bedrock
	Terry McIntyre	Assessment of Phytoremediation as an In-Situ Technique for Cleaning Oil Contaminated Sites.
	Brian Mansfield (new contact: Carl Brown)	Simultaneous Recovery of Inorganic Contaminants and Hydrocarbons from Soils Using Chelation/Solvent Extractions
	Kevin Cash	Assessment of Natural and Anthropogenic Impacts of Oil Sands Contaminants within the Northern River Basin
	Carl Brown	Solar Detoxification
POL 2.1.1	Support for the development of technological and other measures to control and reduce emissions of particulate matter.	
	Keith Puckett	Determination of the Concentration, Composition and Sources of Airborne Carbonaceous Particles in Canada
	Lisa Graham	Characterization of Particulates - Transportation Fuels
POL 2.1.2	The design and use of gaseous and liquid hydrocarbon fuels and associated technologies to achieve emissions reductions.	
	Fred Hendren	Engine Cold Start Efficiency
	Russ Robinson	Environmental Impact of the Use of Alternative and/or New Reformulated Fuels and Development of Advanced Engine/Vehicle Technologies for Use in Light and Heavy Duty Motor Vehicles
	Merv Fingas	Environmental Properties of Diesel Ethers
POL 2.2.2	The development of fuel cell, electric and hybrid vehicle components and their supporting infrastructures.	
	Russ Robinson	Fuel Cell Vehicle Life Cycle Emissions and Environmental Assessment
	Russ Robinson	Electric and Hybrid Vehicle Emissions and Environmental Assessments
POL 2.2.4	The optimization of the energy efficiency of transportation systems.	
	Normand Michaud	The St Lawrence Routing Management Support Model

POL 3.2.1	The establishment of cost-effective interconnections of heat sources and sinks at the community level, which promote the use of energy appropriate to its quality	
	Frank Cruickshanks	Advanced Tools and Procedures for Implementing Thermal Energy Storage in Large Institutional Buildings, Commercial Buildings and Community Oriented Applications
POL 3.2.3	Improvements in the design and integration of energy, transportation, water and waste systems and land use to permit progressive, sustainable development of communities.	
	Claude Lefrançois	Integrating Energy Systems for Sustainable Community Development
	Alain David	Energy and Waste
POL 4.3.3	The development of advanced technologies and products for heat management and separation including high efficiency drying.	
	Jocelyn Paré	Applications of Microwave-Assisted Process (MAPtm1) to Solvent-less Synthesis and to Low Solvent, Energy-Efficient Extraction
POL 4.3.5	The development of low energy intensity bioprocessing technologies.	
	Terry McIntyre	Bioprocesses for Renewable Energy Production, and Improved Industrial Energy Efficiency in Canada.
POL 5.1.1	Improving the economics and efficiency of conversion of renewable energy to electricity including related storage, hybrid, and systems technologies	
	Robert Morris	Solar and Wind Energy Resource Assessment
POL 5.2.1	The characterization of Canadian fuels and their emissions for more efficient and environmental benign electricity generation.	
	Don Rose	Environmental Contaminants in Coal and Coal Byproducts
POL 5.2.2	The conversion of fossil fuels to electricity more efficiently with ultra-low environmental emissions.	
	Don Rose	Prevention, Control and Mitigation of Pollution from Stationary Combustion Sources
POL 5.2.3	The capture, treatment, transport, use and storage of CO2 from large point sources.	
	Bill Reynen	Sustainable Development of Coalbed Methane, a Life-cycle Approach to Production of Fossil Energy
POL 6.1.1	The development of a better understanding of the impacts of climate change on the energy sector, improvement in the forecasting of those impacts and the development of some possible response strategies	
	Heather Auld	Climate and Energy in the Toronto-Niagara Region - Integration of Science and Policy
	George Isaac	Canadian Participation in FIRE III/SHEBA
	Sunling Gong	Climate Change and Anthropogenic Aerosols
	Philip Jarrett	Climate Change Impacts on Extremes of Heating, Cooling and Dehumidification Loads
	Bruce Ramsay	Sea Ice Climatology Studies
	Ron Stewart	Water Vapour, Water Cycling, Climate and Water Resources
	Val Swail	Climate Change and Offshore Design Criteria
	Bruce McArthur	Measurement of Aerosol/Cloud Feedback Relationships
	Tom Agnew	Climate/Sea Ice Process Studies Using Satellite Microwave
	Terry Prowse	Climate Change Impacts on Hydrologic Cycles and Extremes, with a Specific Focus on the Hydro-Electric Industry in Western Canada
	Gérald Vigeant	Gulf of St. Lawrence Ice-Ocean-Atmosphere Climate Change, Detection and Impact on the Canadian Energy Sector.
POL 6.2.1	The development of a better understanding of the relevant natural GHG cycles; and steps to increase the net GHG uptake from the atmosphere by forests, agricultural lands and oceans	
	Alan Barr	Impact of Variability and Climate Change on Carbon Sequestration in a Boreal Forest
	Henry Hengeveld	Science Advisory on Climate Change
	Kaz Higuchi	Estimation of Terrestrial CO2 Sources and Sinks in Canada.